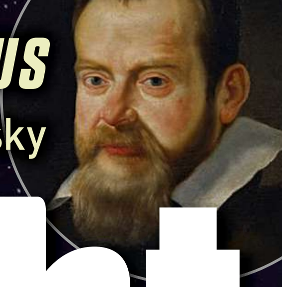
BBC



CELEBRATING GALILEO'S SIDEREUS NUNCIUS

The book's enduring message on our view of the night sky

#190 MARCH 2021

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

The return of AURORA SEASON

Why we see the Northern Lights and how to find them for yourself

ONE FINE SIGHT

When to look for the thin crescent Moon this month

PLANET HUNTERS: THE CELESTIAL POLICE

The 18th-century astronomers whose failed mission found Vesta

BRINGING BACK BENNU

The thrilling story of Osiris-Rex's asteroid sample-return mission

UAE'S HOPE FOR MARS

Inside the Emirates' pioneering mission

ASTRO CAMERA 101

Get to know your CCDs from your DSLRs

STEALTHY SINGULARITY

Scientists locate the closest black hole to Earth

ISSET PRESENTS
MISSION DISCOVERY
"The most welcoming, fascinating and challenging *(in a good way)* experience ever!"
Grazia, Hawthorn High School
5 Day STEM Summer School
Be a Rocket Star
Team up with NASA Astronauts
Improve your UCAS Application
Choose Your Mission
LONDON DUBAI FRANKFURT NEWCASTLE
www.LaunchPrize.com

Welcome

Get ready for this year's awe-inspiring aurora season!

There's one thing about the aurora that I find especially fortuitous, it's that our planet's protective magnetic field transforms deadly radiation from the Sun into an awe-inspiring spectacle. I'll be keeping this in mind as we get into aurora season this month – the time of year when slightly warmer temperatures, improving weather and still-dark nights make a search for the spectacle more rewarding. To help you get the most out of this time, turn to our feature on **page 28**, where Tom Kerss explains the processes behind the Northern Lights and how to see them yourself.

Another event of note in the night sky this month is the opposition of minor planet Vesta, the brightest of the asteroids. In 'The Sky Guide' from **page 43**, you'll find all the details you need to track down this 525km-wide object and make a sighting for yourself. In March it'll be close to the brightest it can reach and makes for an interesting challenge to find with the naked eye!

The story of Vesta's discovery in March 1807 is a fascinating chapter in the history of astronomy, which is faithfully recounted this month by Emily Winterburn. Turn to her feature on **page 60** for a story involving professional jealousy, multiple setbacks and an international group of observers known as the Celestial Police.

Setbacks also feature in Will Gater's feature about the OSIRIS-REx mission on **page 35**. He speaks to mission scientists about the difficulties they overcame in their task to retrieve samples of pristine material from asteroid Bennu, deep in space, as they prepare the laden spacecraft to begin its two-year return journey to Earth in May.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 25 March.

HOW TO CONTACT US

Subscriptions, binders and back issues
03330 162119*
Mon–Fri 9am–5pm

*Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. If calling from overseas, please dial +44 (0)1604 973727

Editorial enquiries
+44 (0)117 300 8754
9.30am–5.30pm, Mon–Fri

Advertising enquiries
+44 (0)117 300 8145

Print subscription enquiries
www.buysubscriptions.com/contactus

Digital subscription enquiries
www.buysubscriptions.com/contactus

Editorial enquiries
contactus@skyatnightmagazine.com

Subscription enquiries
UK enquiries: FREEPOST IMMEDIATE MEDIA (please write in capitals)
Overseas enquiries: PO Box 3320, 3 Queensbridge, Northampton NN4 7BF, UK

Editorial enquiries
BBC Sky at Night Magazine, Immediate Media Co Bristol Ltd, Eagle House, Colston Avenue, Bristol BS1 4ST

Become an Insider

The more we know about what you like, the better placed we are to bring you the best magazine possible. So we'd like to invite you to join our online reader panel 'Insiders'. Just log on to **www.immediateinsiders.com/register** to fill out the short registration survey and we'll be in touch from time to time to ask for your opinions on the magazine and other relevant issues.

Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

Online
Visit our website for competitions, astrophoto galleries, observing guides and more

Social media
Follow us on Twitter, Facebook and Instagram for space news, astro images and website updates

Podcasts
Listen to our Radio Astronomy podcasts where the magazine team and guests discuss astro news

Tablet/phone
Get each month's issue on your Apple or Android device, now with bonus image galleries

eNewsletter
The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

Find out more at: www.skyatnightmagazine.com

28

CONTENTS

Ⓒ = on the cover

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

This month's contributors

Will Gater

Astronomy journalist

"In 15 years of writing for *BBC Sky at Night Magazine*, I've explored exciting projects, but hearing the inside story of an asteroid sampling was on another level!" **Will looks at NASA's OSIRIS-REx mission at Bennu, page 35**

Tom Kerss

Aurora expert

"Whether staying in the UK or venturing overseas, you can make a plan to go on an aurora-chasing adventure and witness the greatest light show on Earth". **Tom offers tips on catching an auroral display, page 28**

Emily Winterburn

Physicist and historian

"I enjoyed writing about Vesta; I love the way this story shows how productive mistakes can be and why it's important to never give up!" **Emily looks at the role of the 'Celestial Police' in Vesta's discovery, page 60**

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/KSTUQFJ/** to access this month's selection of exclusive Bonus Content

MARCH HIGHLIGHTS

Interview: the SPHEREx survey

NASA scientist Jamie Bock discusses a new mission that will track the history and evolution of the Universe.

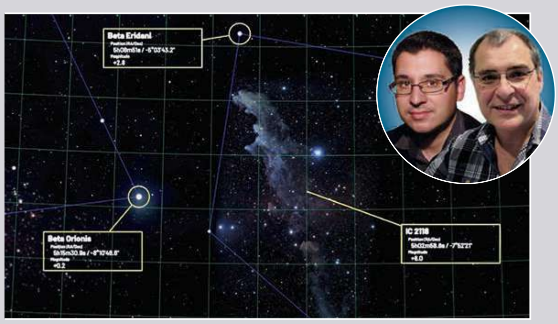
The Sky at Night: Pick of the Year

Chris, Maggie and special guests from the worlds of astronomy and spaceflight pick their top moments from 2020.

Audiobook preview *Lucy in the Sky*

Download and listen to an extract from author Lucy Hawking's podcast about the state of the spaceflight industry.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

NASA/THE SOFIA SCIENCE TEAM/A. BORLAFF/NASA/ESA/S. BECKWITH (STSCI) AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

MAGNETIC MAYHEM

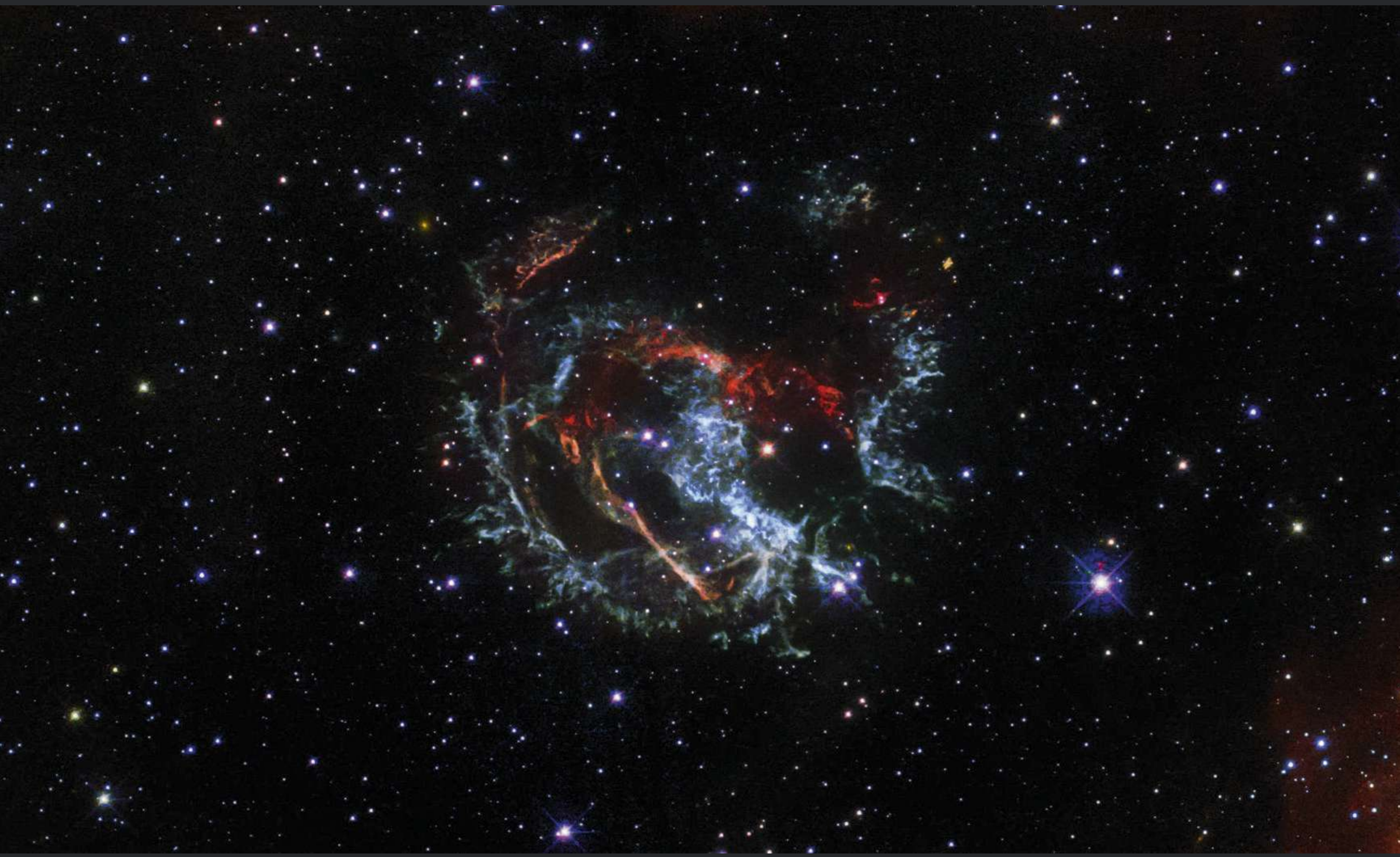
An amazing new far-infrared perspective reveals the chaos in the Whirlpool Galaxy

HUBBLE SPACE TELESCOPE/SOFIA, 14 JANUARY 2021

From its vantage point aboard a Boeing 747SP, 12km above Earth, NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) has revealed the hidden mayhem unfolding in the Whirlpool Galaxy, M51.

By mapping the magnetic fields that course through its graceful, curling arms SOFIA's far-infrared instrument, the High-Resolution Airborne Wideband Camera (HAWC+), uncovers a far more chaotic picture than suggested by previous radio observations.

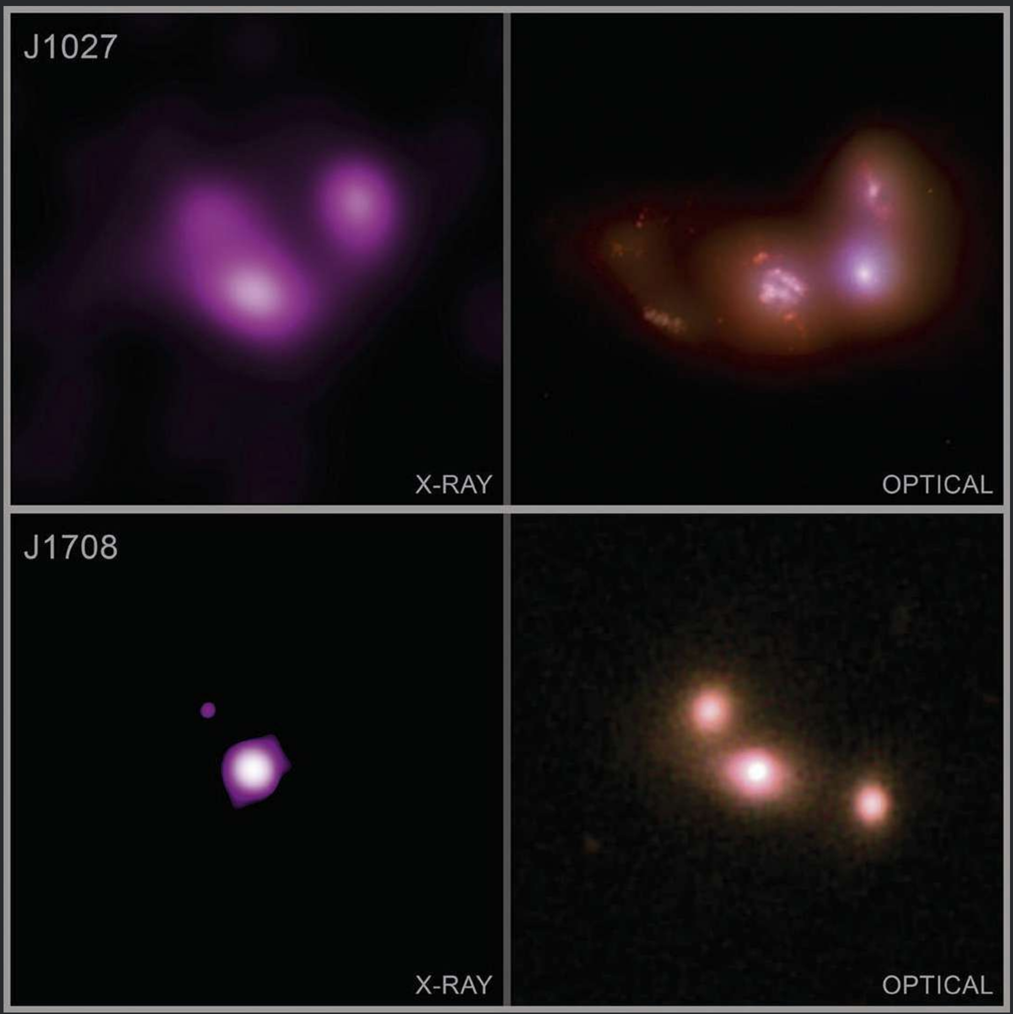
The camera – which detects the polarised light emitted as spinning dust grains align in the presence of magnetic fields – shows that while the fields are relatively orderly near the massive black hole at the galaxy's core, things get far more turbulent in the outer spiral arms, where the streamlines weave back and forth across the structure. Hundreds of red-pink areas of star formation, gas super-heated by supernova explosions and the Whirlpool's small, yellow neighbouring galaxy NGC 5195 may all play a part in the disarray, but we're only just beginning to understand the role magnetic fields play in star and galaxy evolution.



△ Rewinding time

HUBBLE SPACE TELESCOPE, 15 JANUARY 2021

In what seems an impossible task, researchers have located the centre and the age of a star that went supernova 1,700 years ago. By scrutinising historic images of supernova remnant 1E 0102.2-7219, part of the Small Magellanic Cloud, they have retraced the expanding debris – still expanding from the blast site at 3.2 million km/h – back to the third century AD.

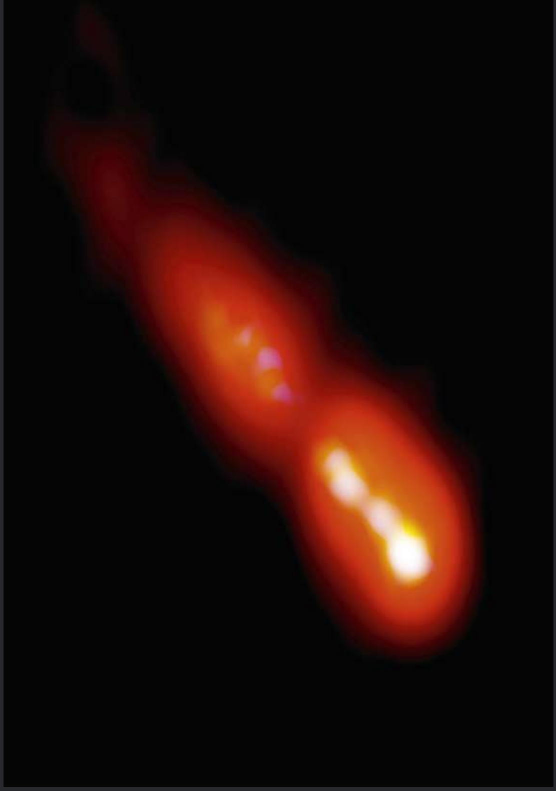


Triple trouble ▷

CHANDRA X-RAY OBSERVATORY/HUBBLE, 14 JANUARY 2021

What's left of their black holes when three vast galaxies crash together? Using Chandra's X-ray vision, a new study found that in six of seven mergers, one contained a triple giant black hole, four had doubles (of which two are pictured here) and one a single. The triple giant may help us understand how the biggest black holes and galaxies evolve.

NASA/ESA AND J. BANOVETZ AND D. MILISAVLJEVIC (PURDUE UNIVERSITY), X-RAY: NASA/CXC/UNIV. OF MICHIGAN/A. FOORD ET AL/OPTICAL: SDSS & NASA/STSCI, SPINGOLA ET AL/BILL SAXTON, NRAO/AUI/NSF, ESO/TIMER SURVEY



◁ In a blazar glory

VERY LONG BASELINE ARRAY, 22 DECEMBER 2020

You could be forgiven for thinking this flash is a meteor, but it is a colossal jet of material ejected from the core of a galaxy (in the bottom right) and barrelling towards us at nearly the speed of light.

At 12.8 billion lightyears from Earth, galaxy PSO J0309+27 in Aries is the brightest radio-emitting blazar yet seen at such a distance. Propelled by a supermassive black hole, its jet extends some 1,600 lightyears into space.

▽ Stunning starbursts

VERY LARGE TELESCOPE, 11 JANUARY 2021

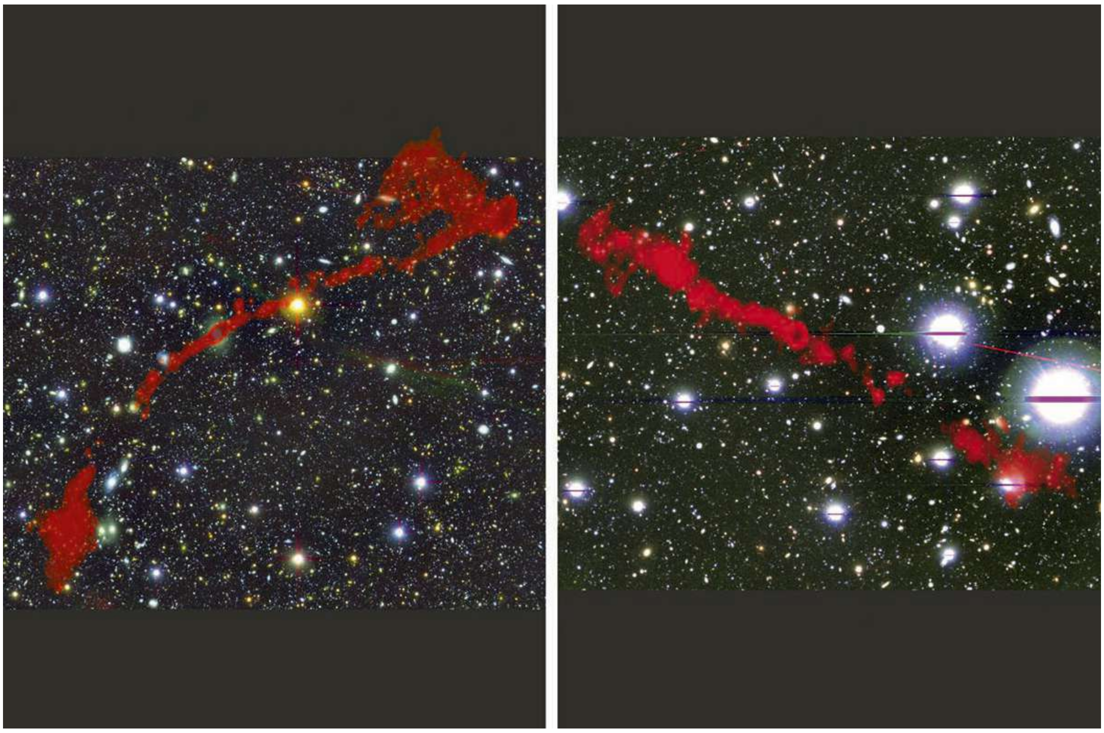
An intriguing bejewelled ring sits at the centre of NGC 1097, a barred spiral galaxy in the constellation of Fornax, the Furnace. Just 5,000 lightyears wide, in a galaxy stretching tens of thousands of lightyears beyond it, the ring glitters with hundreds of spots of pink and purple. Each one is a region bursting with new star formation, while dark lanes of debris, gas and dust fall inwards to the maw of a supermassive black hole, which is 140 million times more massive than our Sun.

MORE **ONLINE**

A gallery of these and more stunning space images

The latest astronomy and space news, written by Ezzy Pearson

BULLETIN



▲ **Big shots: the two giant radio galaxies found with the MeerKAT telescope, with their light shown in red**

Two cosmic giants are among the brightest objects in the Universe

Giant radio galaxies may be more common than previously thought

A pair of gargantuan galaxies, which could be among the largest single objects in the Universe, have been unearthed by the MeerKAT telescope array in South Africa.

"They are more than 2 megaparsecs across, which is around 6.5 million lightyears, or 62 times the size of the Milky Way," says Matthew Prescott from the University of the Western Cape, who took part in the study.

Such galaxies are extremely rare, so it's unusual that the two were discovered so close to each other.

"We found these giant radio galaxies in a region of sky that is only about four times the area of the full Moon," says Jacinta Delhaize from the University of Cape Town, who led the study. "Based on our current knowledge of the density of giant radio galaxies in the sky, the probability of finding two of them in this region is less than 0.0003 per cent. This means that giant radio galaxies are probably far more common than we thought."

The apparent rareness of giant radio galaxies had been a puzzle for astronomers. It's currently thought that the behemoths are normal radio galaxies which have grown old and expanded to enormous size, but if this were the case the number found would be more in line with their younger counterparts.

This problem could soon be resolved, however. MeerKAT is a precursor to the much more powerful Square Kilometre Array (SKA) telescope, which will be able to detect more radio galaxies than any telescope before it. The SKA's two giant arrays in South Africa and Australia are due to be completed in 2027, but could start observing from 2023.
www.sarao.ac.za

Comment

by Chris Lintott

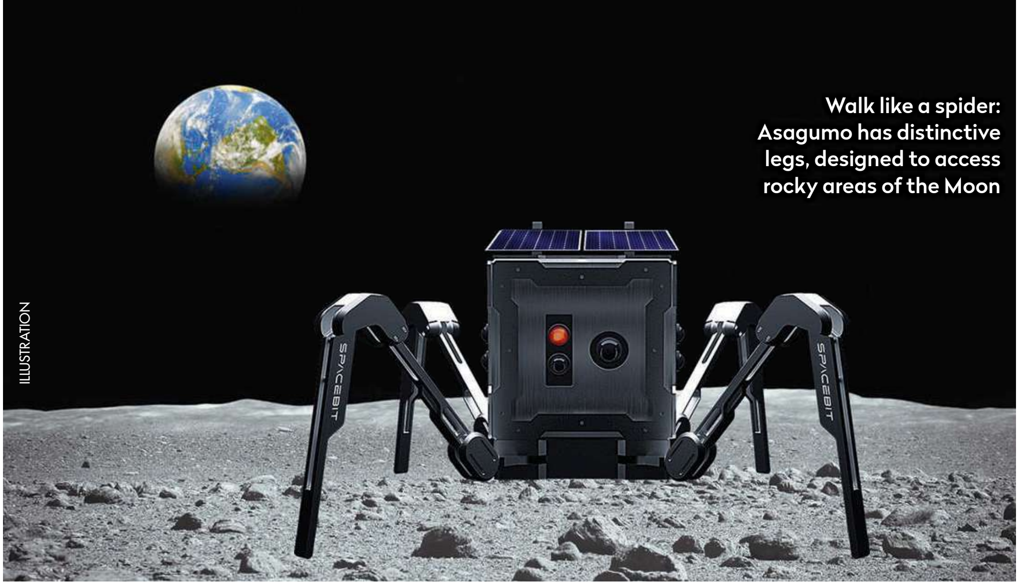
Something as big as a giant radio galaxy should be easy to find but it's a huge challenge: because their jets extend over a large area of the sky, even quite luminous examples are faint against the bright background of the radio sky.

Finding these two giants is an exciting sign that the new MeerKAT telescope is up to the challenge. It's more impressive when you consider that these discoveries are larger, and have lower radio power, than most known examples.

The jets are produced by activity around the host galaxy's central black hole, and then expand and fade over time. The existence of large, faint giants has been predicted, so this result matches our understanding of how these objects evolve.

Chris Lintott co-presents *The Sky at Night*

I. HEYWOOD (OXFORD/RHODES/SARAO), NARVIKK/ISTOCK/GETTY IMAGES, HTTPS://SPACEBIT.COM, NASA/JPL-CALTECH X 2



Walk like a spider: Asagumo has distinctive legs, designed to access rocky areas of the Moon

UK rover set to launch for the Moon in 2021

The British lander could soon be scuttling across the Moon

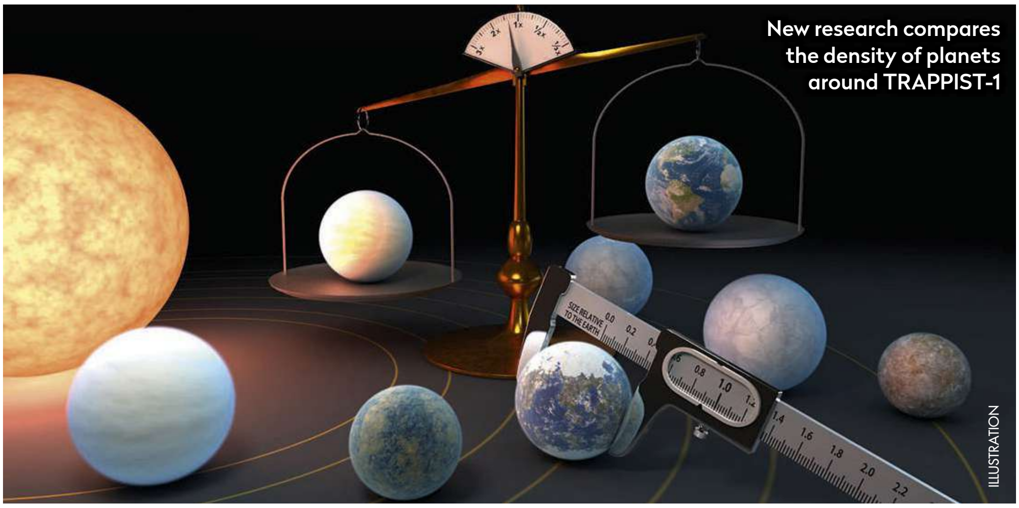
The UK could be walking on the Moon in 2021, after London-based company Spacebit announced it is on course to launch its Asagumo rover in the second half of the year. The rover has an unusual design, with four spider-like legs rather than the traditional wheels or tracks.

"It will be walking across the Moon, not driving, so it can go on rugged terrain and explore those parts you can't get to normally," Pavlo Tanasyuk, CEO of Spacebit said in an interview with *The Telegraph*.

Though the mission is designed primarily to test the technology, Asagumo will be capable of taking images and measuring radiation, and future iterations could be used to scout out precious metals or minerals.

The spacecraft will travel to the surface alongside other rovers and scientific experiments onboard the inaugural flight of Astrobotic's Peregrine Moon lander – a private enterprise that offers to deliver payloads to the Moon. **https://spacebit.com**

Surprise similarities in TRAPPIST-1's seven worlds



New research compares the density of planets around TRAPPIST-1

After thousands of hours of observations, researchers have discovered that the worlds of TRAPPIST-1 have a similar composition, with a density 8 per cent lower than Earth's.

TRAPPIST-1, a red dwarf star, made news in 2017 when seven planets were discovered in orbit around it. Since then, a host of telescopes have been studying the system – including over 1,000 hours of observing time with NASA's Spitzer telescope.

"This could mean that they contain roughly the same proportion of material that make up most rocky planets... and our planet," says Elsa Ducort from the University of Leige in Belgium, who led the Spitzer analysis.

The planets' slightly lower densities could either be due to a different distribution of iron, or a higher abundance of water.

"The TRAPPIST-1 system is fascinating; around this star we can learn about the diversity of rocky planets within a single system," says Caroline Dorn from the University of Zurich. **www.uliege.be**

NEWS IN BRIEF

Mars dig scrapped

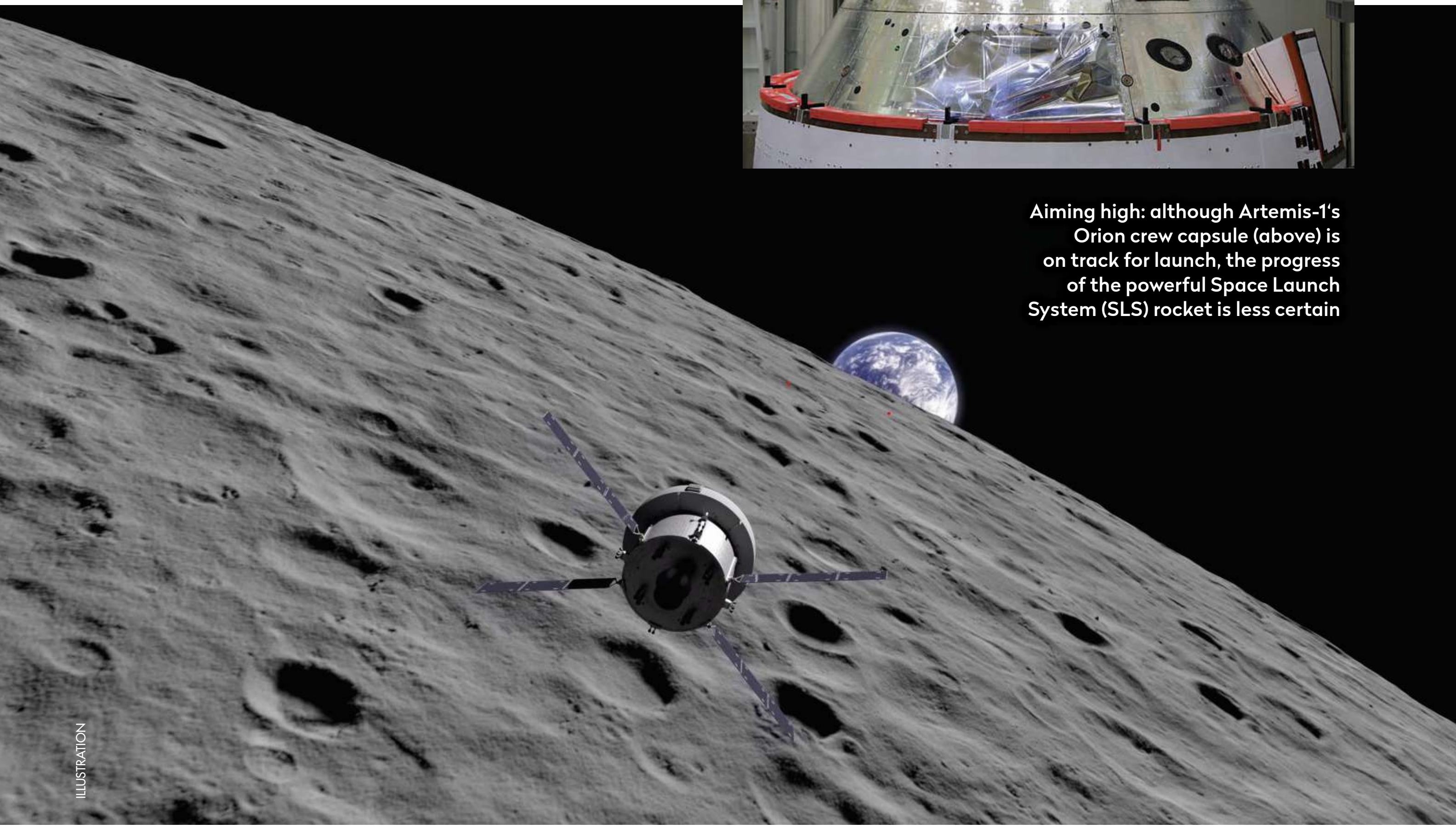
NASA has abandoned efforts to drive the heat probe of its InSight lander into the surface of Mars after two years of trying. "We've given it everything we've got but Mars and our heroic mole [probe] remain incompatible," says Tilman Spohn, primary investigator of the probe.

Tipping Saturn

Saturn's 27° axial tilt could be due to its many moons. A recent study found the moons are gradually moving away from the planet, potentially pulling it over as they go. The planet is still tipping over and its inclination could more than double in the next few billion years.

Cloud-free Jupiter

A cloudless Jupiter-like planet has been spotted for the first time. While looking at an exoplanet's atmosphere, astronomer Munazza Alam found a clear observation of sodium, the light of which would have been blocked out if there were clouds present.



Aiming high: although Artemis-1's Orion crew capsule (above) is on track for launch, the progress of the powerful Space Launch System (SLS) rocket is less certain

ILLUSTRATION

▲ To the Moon, and beyond: over the course of the next decade, NASA is aiming to establish a sustainable presence on the Moon

Biden's NASA still on course for the Moon

Artemis is still pressing forward, though new delays could put a 2024 landing in jeopardy

When new US president Joe Biden took his seat in the Oval Office, he was joined by an unusual companion – an Apollo Moon rock. The lunar relic is currently resting on a bookshelf and is believed to be representation of his administration's commitment to science.

The change in administration is not just at the White House, however. Jim Bridenstine stepped down from his role as NASA's administrator on 20 January and is being replaced temporarily by former associate administrator Stephen Jurczyk. This is normal during a change of presidency, as the position is a political one and new Presidents often have a different vision of the direction NASA should be taking during their time in office.

Whoever steps into the role is in for a challenge however, as NASA is currently taking on one of its most ambitious projects yet – Artemis, which aims to put the first woman on the Moon by 2024.

This deadline, however, is looking increasingly precarious. The first mission of the programme, Artemis-1 – which will serve as an orbital trial of both the Orion crew capsule and its heavy launch rocket, the Space Launch System (SLS) – had been scheduled for a November 2021 launch. While the Orion capsule is on track to meet that date and was transferred to the Kennedy Space Center on 14 January for final launch preparations, the SLS's readiness is less certain.

The rocket is already several years behind schedule, but is finally undergoing its 'Green Run' test campaign to clear it for flight. But yet more delays during these tests means there is now no more slack in the schedule. Then, on 16 January, a test fire of the rocket engine cut out after one minute rather than the expected eight due to an anomaly in one of the engines. NASA now plans on re-running the test in late February, meaning the Artemis-1 launch will almost certainly be pushed back to early 2022. If so it will be extremely challenging, if not impossible to meet the 2024 deadline for a crewed mission.

As of writing, President Biden had yet to make an official announcement about Artemis, but if his bookshelf is to be believed there seems little risk of its cancellation. US boots will be returning to the Moon – it's just a question of when.

www.nasa.gov

NASA X 2, ESO/M. KORNMESSER

Galaxy caught in death throes

Astronomers have caught a galaxy on the verge of death as it throws away its gas and dust, preventing it from forming new stars.

Galaxy ID2299 is hurling out around 10,000 solar masses of material every year in an elongated stream of gas and stars known as a tidal tail. At this rate, the galaxy will have lost half its gas within a few tens of millions of years.

"This is the first time we have seen a typical massive star-forming galaxy in the distant Universe about to 'die' because of a massive cold gas ejection," said Annagrazia Puglisi from Durham University, who led the study.

It's thought that ID2299 is the result of two galaxies crashing together, the turmoil of their collision resulting in a huge amount of gas being kicked out of the galaxy.

ILLUSTRATION

NEWS IN BRIEF

Juno lives on

NASA has extended the Juno mission, which has been looping its way around Jupiter since 2016. The spacecraft was going to be crashed into the planet this July, but it has been weathering Jupiter's intense radiation surprisingly well, meaning its demise has been pushed back to 2025.

Resurrecting Arecibo

Astronomers have drawn up plans to replace the Arecibo Telescope in Puerto Rico, which collapsed in December 2020. If commissioned, the new telescope would replace the original's 305m-dish with 1,000 smaller antennae on a platform that would tilt to observe different areas of the sky.

1,000 Starlink satellites

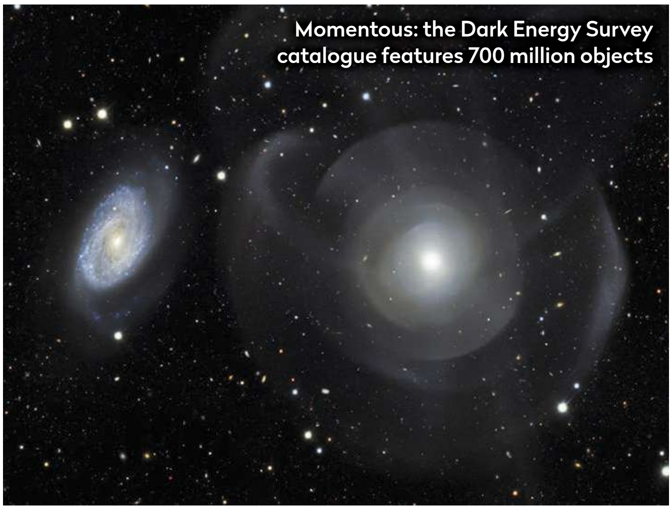
SpaceX launched its 1,000th Starlink telecommunications satellite on 20 January 2021. After early concerns about light pollution, the company has been working with astronomers to dim the satellites' reflections, adding shading visors in August, though they remain bright enough to affect astronomical observations.

NASA/JPL, DES/DOE/FERMILAB/NCSA & CTIO/NOIRLAB/NSF/AURA, NOIRLAB/NSF/AURA/J. DA SILVA, NASA/JPL-CALTECH/ASI/USGS

BULLETIN

Galaxy catalogue shines light on dark energy

The survey aims to track the expansion of the Universe


Momentous: the Dark Energy Survey catalogue features 700 million objects

The Dark Energy Survey (DES) has released its second tranche of data, detailing more than 700 million astronomical objects, making it one of the biggest deep-sky catalogues to date.

The survey has spent six years mapping the positions of galaxies across 5,000 square degrees of the southern sky, with the goal of using them to measure how fast the Universe is expanding. Previous observations show this expansion is accelerating under the influence of a hypothetical dark energy, which drives galaxies apart from each other.

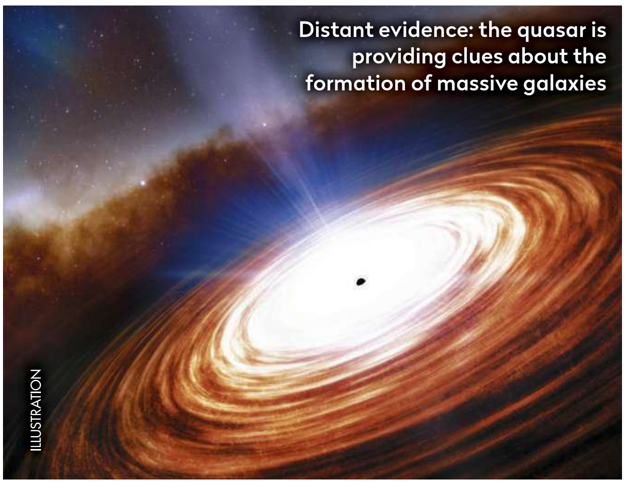
The release now opens up the data to other branches of astronomy – from those investigating the gravitational waves from distant galaxies to those mapping the dwarf satellites around our own. "We invite professional and amateur scientists alike to dig into what we consider a rich mine of gems waiting to be discovered," says Rich Kron from Fermilab, director of the survey.

www.darkenergysurvey.org

Quasar gives insight into origins of black holes

The most distant quasar ever seen – the light of which dates back to just 670 million years after the Big Bang – has been spotted for the first time.

A quasar is a galaxy with a supermassive black hole at its heart that consumes vast amounts of gas. This causes the central region to superheat and outshine its host galaxy. In this case, the black hole weighs a massive 1.6 billion solar masses, which creates something of a quandary.

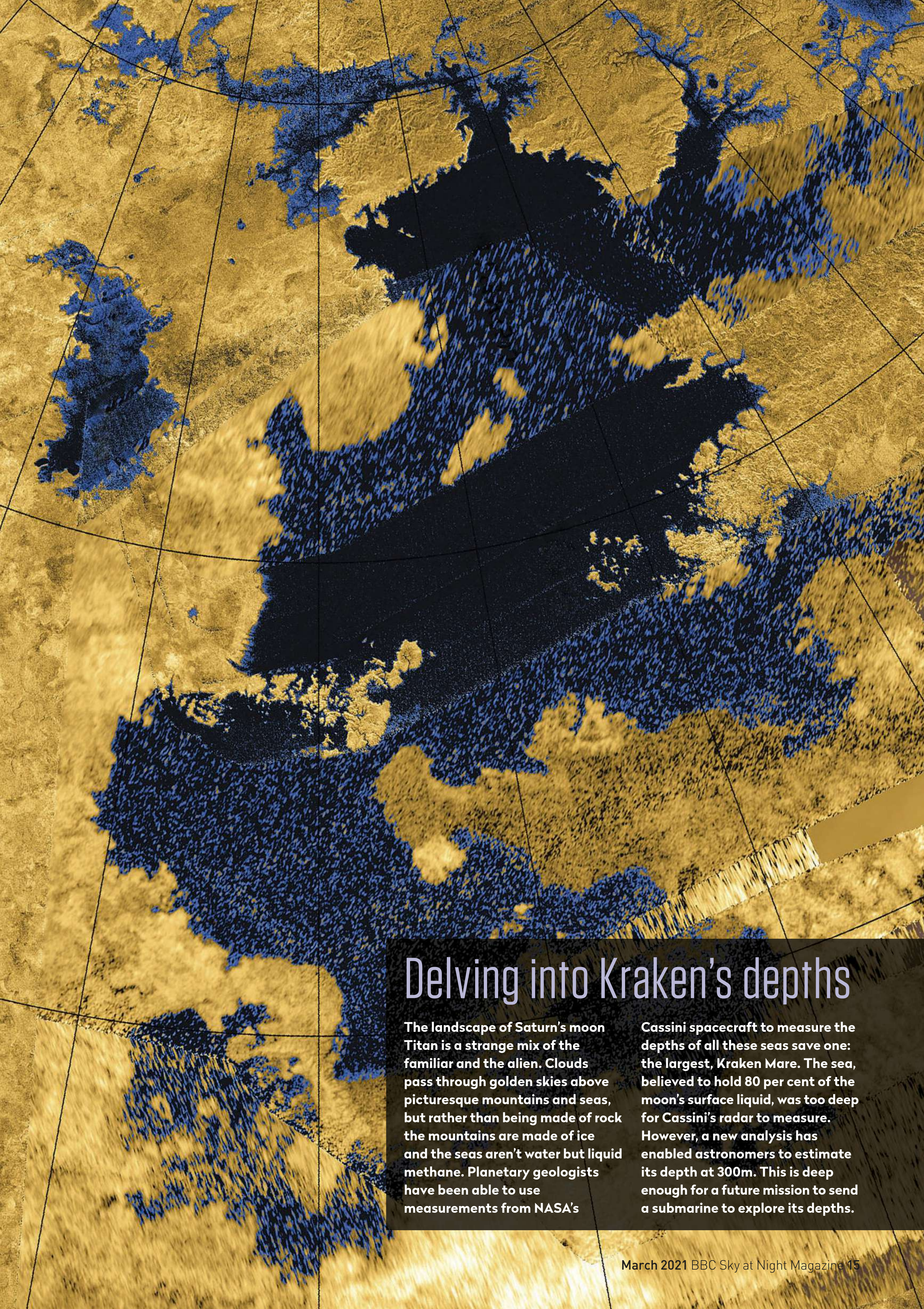


Distant evidence: the quasar is providing clues about the formation of massive galaxies

"Black holes created by the first massive stars could not have grown this large in only a few hundred million years," says Feige Wang from the University of Arizona, USA, who led the research team.

The researchers have also discovered that the host galaxy is going through a growth spurt, as it forms new stars 200 times faster than the Milky Way. Combined with the quasar's age and size, astronomers hope the object will provide a 'natural laboratory' where they can investigate how such black holes and their galaxies grew in the early stages of the Universe.

http://noirlab.edu



Delving into Kraken's depths

The landscape of Saturn's moon Titan is a strange mix of the familiar and the alien. Clouds pass through golden skies above picturesque mountains and seas, but rather than being made of rock the mountains are made of ice and the seas aren't water but liquid methane. Planetary geologists have been able to use measurements from NASA's Cassini spacecraft to measure the depths of all these seas save one: the largest, Kraken Mare. The sea, believed to hold 80 per cent of the moon's surface liquid, was too deep for Cassini's radar to measure. However, a new analysis has enabled astronomers to estimate its depth at 300m. This is deep enough for a future mission to send a submarine to explore its depths.

Scientists are challenging the traditional view that the asteroid belt is a depleted reservoir of planetesimals

Origin of the asteroid belt

Did the asteroid belt start full and empty out, or start empty and then get filled up?

Astronomers know a lot about the asteroid belt. Marking the boundary between the inner rocky planets and the outer gas giants, it is the widest swathe of Solar System real estate between Mercury and Neptune that does not contain a major planet. The total mass of this sparse region of rocky rubble is a mere one-thousandth that of Earth's, and a single asteroid, Ceres, comprises almost a third of this total mass. The inner asteroids are mostly dry, S-class (siliceous) objects thought to be most similar to ordinary chondrite meteorites, whereas C-class (carbonaceous) objects dominate the outer belt and are loaded with carbon and water. The orbits of the asteroids are also, on the whole, what is known as 'dynamically excited' – their circuits around the Sun aren't neat circles within the plane of the Solar System, but have orbital eccentricities of up to 0.3 and can be inclined at angles of over 20°.

Despite how well we can characterise the asteroid belt today, we don't actually know for certain how it came about in the first place. But now Sean Raymond, at the Astrophysical Laboratory at the University of Bordeaux and David Nesvorný of the Department of Space Studies, Southwest Research Institute, Boulder, Colorado have been reviewing what is known about its origins.

A new perspective

As Raymond and Nesvorný discuss, the classical view is that the asteroid belt formed within the gassy, dusty disc swirling around the primordial Sun, as a swarm of leftover planetesimals, with an initial mass of perhaps several Earth masses in total. Over time, so this hypothesis goes, 99.9 per cent of this material was ejected out of this orbital region by gravitational interactions from the planets (including the possible early migration of Jupiter and Saturn) – and so the asteroid belt we observe today represents the remnants of a heavily depleted reservoir of planetesimals. But the opposite process could explain the characteristics of the modern asteroid belt too. Perhaps this orbital region actually started with no rocky material in it at all, and it has been filled up over Solar System history with planetesimals born elsewhere in the Solar System – in this way, the sculpting of the asteroid belt may be a story of accumulation rather than depletion.

"Perhaps this orbital region started with no rocky material and has been filled-up with planetesimals born elsewhere in the Solar System"

One clue to what happened, explain Raymond and Nesvorný, may be provided by the two largest asteroids, Ceres and Vesta. While Ceres and Vesta currently occupy relatively close orbits (indeed, there's a chance they may collide in the next billion years or so...) it is likely that they actually formed in vastly different environments in the primordial Solar System. NASA's Dawn space probe confirmed that Ceres is rich in water ice and has a composition most similar to carbonaceous chondrite meteorites. This giant asteroid is thought to have formed in the cold outer Solar System, but was dislodged and implanted into the asteroid belt by the formation of the gas giants. Vesta's composition, on the other hand, suggests that it was scattered into the asteroid belt from its birthplace much closer to the Sun. A mark for accumulation perhaps?

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Origin and dynamical evolution of the asteroid belt* by Sean N. Raymond and David Nesvorný. **Read it online at: https://arxiv.org/abs/2012.07932**

Our neighbourhood black hole

The massive object could be hiding among the stars of Monoceros

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Black holes are having something of a moment. The last few years have seen the detection of gravitational waves from colliding black holes, and there was the Event Horizon Telescope's magical image of the shadow of the large black hole that lurks at the heart of M87. Last year saw the Nobel Prize split between Roger Penrose for his theoretical study of these enigmatic objects and the two teams who have monitored the movements of stars around Sagittarius A* – our own Galaxy's supermassive black hole.

With so much attention, it's somewhat surprising to hear that we may not know where our nearest black hole is. The problem is that they are, well, black – a lone black hole wandering through the Galaxy would be nearly impossible to spot. Things are easier when the black hole in question is the companion to a normal star, and the team behind this month's paper think they've spotted just such an object.

The star in question is V723 Monocerotis, a bright red giant 1,500 lightyears away from the Sun. It has long been catalogued as an eclipsing binary – a double star that fluctuates in brightness as the two components pass in front of each other. New data, from NASA's exoplanet-hunting TESS (Transiting Exoplanet Survey Satellite) mission, the All Sky Automated Survey (ASAS) and the brilliantly named Kilodegree Extremely Little Telescope (KELT), has led to a rethink.

A mysterious companion

V723 is indeed a double system but a rarer ellipsoidal variable. The red giant is being pulled out of shape by an unseen companion, and this distortion means it changes brightness as it completes its orbit. But what is the companion? There is no obvious star contributing to either the system's spectrum or the observed changes in brightness. In a few recent cases, systems that astronomers thought might contain black holes turned out to be disappointments, containing normal stars so hot that they didn't significantly contribute to the visible spectrum. Here, we know how much ultraviolet light the system emits and so it can't be hiding a hot, massive companion.

"The red giant is being pulled by an unseen companion, and this distortion means it changes brightness as it completes its orbit"

As a result, the second object has to be a compact object, either a black hole or a neutron star. The behaviour of the giant suggests that the unseen companion weighs in a little under three times the mass of the Sun; this is just under the theoretical maximum mass for a neutron star, but it would make it by some distance the most massive such object known. As a result, the authors suggest that a black hole is the most likely explanation.

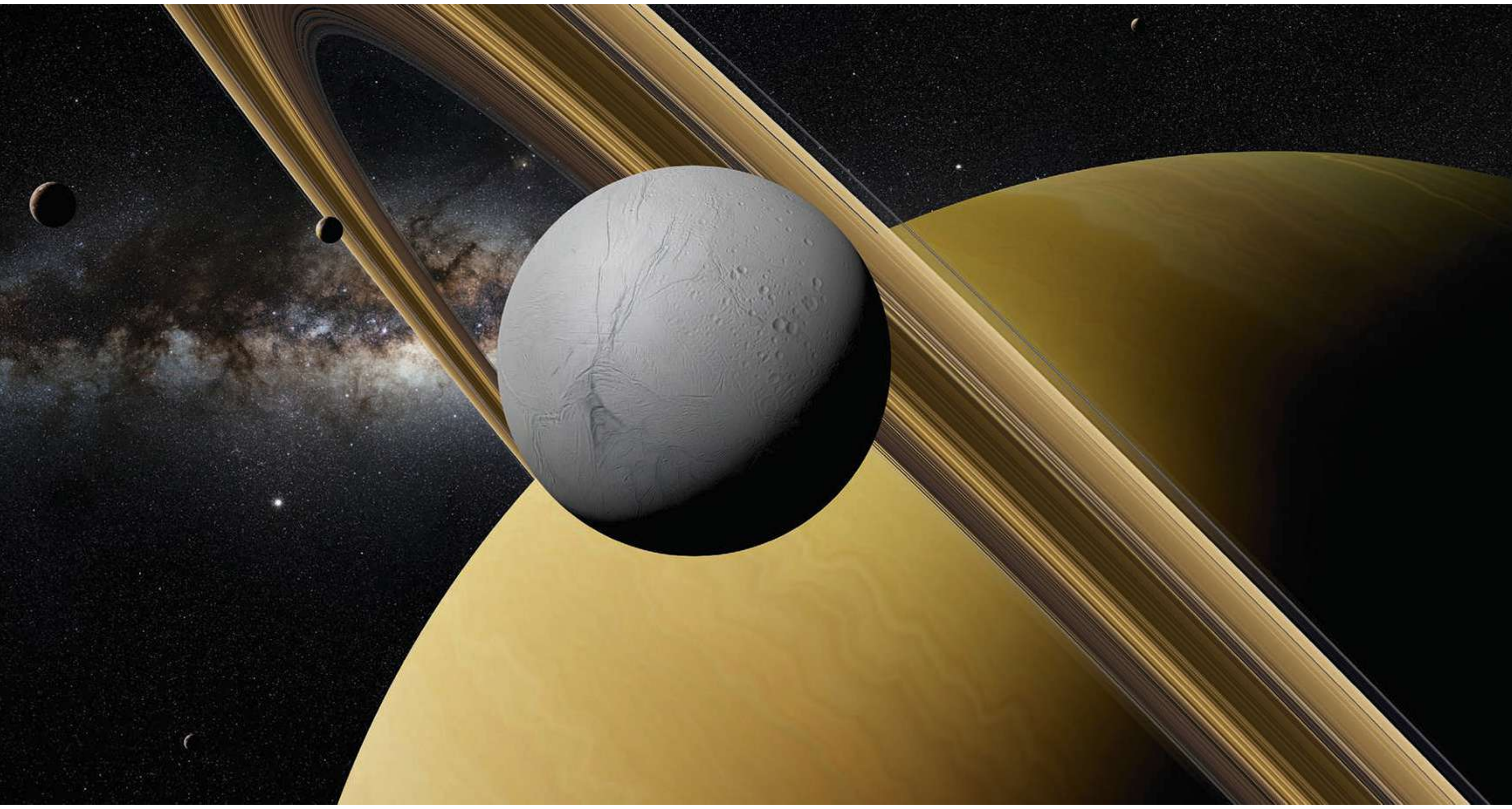
If that's right, this is a record-breaking system. It would be the closest known black hole, and the lowest mass black hole found in this sort of system. In fact, it would be right in the middle of the so-called mass gap that sits between the lowest mass black holes known and the heaviest neutron stars. All sorts of explanations have been proposed over the years for why such a gap should exist, but if these results from V723 bear out then it may just be that the smallest black holes have been there all along, waiting for us to find them.

Is a black hole pulling the red giant V723 Monocerotis out of shape?

Chris Lintott was reading... *A Unicorn in Monoceros: the 3M dark companion to the bright, nearby red giant V723 Mon is a non-interacting, mass-gap black hole candidate* by T. Jayasinghe et al.
Read it online at: https://arxiv.org/abs/2101.02212

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



▲ **Realms of possibility: if evidence of life was found in places such as Saturn's moon Enceladus (above) or Jupiter's Europa, this could be key to proving its existence on Earth isn't just by chance**

Astronomer Royal **Martin Rees** looks at how humanity's search for life beyond Earth might change in the coming years

As a pretext to re-reading Arthur C Clarke's prophetic book *Profiles of the Future* (1962), last year I gave a lecture in his honour. He would have been disappointed that, more than 50 years after Neil Armstrong's 'one small step', the Apollo program is still the high point of human spaceflight. But he would have applauded the probes to Mars, such as Perseverance which is due to arrive at the planet in February. The rover is the latest in a line of missions that have scouted the surface for signs of life, both past and present. It is the first stage of an initiative to bring rock samples back to Earth, giving us our best chance yet of answering the question, "Is there life beyond Earth?"

And he would have been excited by Saturn explorer Cassini and its Huygens probe that landed on Titan; as well as the images of Pluto taken by New Horizons. These probes took decades to develop, build and reach their destinations, during which time robotics and computers greatly evolved. Today, improved robotics would allow vastly more sophisticated probes, with advanced AI (artificial intelligence) controlling them much more ably.

But for all who are fascinated by extraterrestrial life the most transformative discoveries lie beyond our Solar System, on planets around other stars. Among them are millions the size of our Earth, on orbits with temperatures such that water neither boils nor stays frozen – the 'habitable zone'.

Looking for life

For most of us the number one question is, "Do these planets have a biosphere – perhaps even intelligent inhabitants?" Within 10 years, the European Extremely Large Telescope (E-ELT) in Chile, with a mosaic mirror measuring 39m-across, will be able to seek out the distinctive features of a biosphere. But even if biospheres are widespread, advanced life could still be rare, so how might it reveal itself?

It's best to be guided by what may happen on Earth. The history of human technological civilization

DOTTEDHIPPO/ISTOCK/GETTY IMAGES, JEREMY SUTTON-HIBBERT/ALAMY STOCK PHOTO, GWENGOAT/ISTOCK/GETTY IMAGES, NASA

Martin Rees is the Astronomer Royal, and served as president of the Royal Society from 2005-10

is measured in millennia (at most). And it may be only a few more centuries before humans are transcended by inorganic intelligence, which could then persist, evolving on a faster-than-Darwinian timescale, for billions of years. 'Organic' human-level intelligence could be a brief interlude before machines take over.

If intelligence on another world evolved as it might here, we'd be most unlikely to 'catch' it in the brief sliver of time when it was still embodied in an organic form. We would be far more likely to detect electronic intelligence, rather than creatures of flesh and blood.

We must drastically reinterpret how we approach the Search for Extraterrestrial Intelligence (SETI). The lifetime of an 'organic' high-tech civilization may be millennia at most, but its electronic diaspora could continue for billions of years.

The big uncertainty is the actual origin of life. It's possible that it only happened once – here on Earth. That's why probes to the outer planets are important; if there were even 'primitive' life under the ice of Europa and Enceladus or methane-based life on Titan, it would imply that life had started twice in one planetary system. This would have huge implications: life would be expected to have emerged in billions of locations in the Milky Way – manifesting in a variety beyond the imaginings of science fiction writers.

Looking back: The Sky at Night

20 March 1961

On the 20 March 1961 episode of *The Sky at Night*, Patrick Moore was joined by bacteriologist Francis Leslie Jackson from King's College London. While most of Jackson's work looked at terrestrial bacteria, he was interested in the possibility of finding living organisms on other planets. For the show, Jackson subjected bacteria to the conditions found on other planets – such as the low-pressure carbon dioxide rich atmosphere of Mars or the acidic high-pressure atmosphere of Venus – to see how they fared.

▲ **Astrobiology enabled greater insight into the detection of phosphine in the clouds of Venus**

This type of work has since blossomed into an entire field of study known as astrobiology. Some researchers run more refined versions of the experiments run by Jackson in the 1960s. Others, like our own Lewis Dartnell who's monthly column you can read in the 'Cutting Edge' section, travel the world visiting the more extreme environments – from super-salty lakes to the driest deserts. Here they look for organisms, attempting to understand the limits of what life can survive, as well as identifying potential 'bio-markers' which might betray the presence of similar life forms on other planets. It was research like this that found that bacteria in oxygen-deprived environments give off the chemical phosphine which was recently detected in the skies above Venus, leading to hope that bacteria might exist in the planet's toxic clouds.

The Sky at Night is taking a well-earned break this month and is due to return later in the year. You can still get your astronomy fix via its official BBC Four website, where you'll find recent episodes on the first all-female spacewalk, the search for life on Venus and humanity's fascination with Mars. There's also a collection of archive episodes featuring the late Patrick Moore, plus stargazing tips, astrophoto galleries and astronomy tutorials. Visit **www.bbc.co.uk/programmes/b006mk7h**

▲ **Watch an interview with NASA astronaut Jessica Meir, who took part in the first ever all-female spacewalk in October 2019**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

This month's top prize: four Philip's titles

PHILIP'S The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, Heather Couper and Nigel Henbest's *2021 Stargazing*, and a planisphere for the night skies as they appear at latitude 51.5° north.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

MESSAGE OF THE MONTH

You need patience to find the Horsehead Nebula

Horsehead hunt

I enjoyed Pete Lawrence's article on the Horsehead Nebula ('Sky Guide Challenge', January 2021 issue). It's an object I've been interested in seeing for a long time, and it spurred me on to have a go. On 6 January there was a break in the clouds and very clear skies. I have moderate light pollution here on Anglesey and the conditions seemed as good as they could get, with the Milky Way bright to the naked eye.

Following the article's guidance, the starting point was Altinak. The Flame Nebula was visible in my 14-inch Newtonian without filters which was a very good sign, as was the nebulosity around HIP 26816. I started to explore the area occupied by IC 434 with an H-beta filter in place, and as my eyes adapted to the dark I began to see hints of nebulosity there too. At last I began to detect what seemed at first like a dark, roundish hole in the nebulosity at the correct location, and after about an hour of dark adaptation this became a clear, dark bite out of IC 434 with hints of the classic equine profile – I was delighted to see the Horsehead! The best view was at 80x magnification; I tried higher powers but they didn't help. Thanks again for your fine article and inspiration.

Richard Bleasdale, Birmingham

That's brilliant, Jim. Taking you time to let your vision fully adapt to dark conditions has certainly paid off for you! ***– Ed.***

Tweet

Robert Leach
@Dovber90 • Jan 28
North America Nebula in HOO – different palette adds a bit of pop – my first ever narrowband data from last year reprocessed. Nice to see progress.
@skyatnightmag @AstroBackyard

HORST ZIEGLER/CCDGUIDE.COM

Simon's shot of the Orion Nebula

Catching Orion

I've always been interested in astronomy and for years I've been intrigued by astrophotography. I've had many failed attempts; the process always seemed so complicated. I promised myself that one day I'd be able to take a passable picture of the Orion Nebula. I spent lockdown studying polar alignment, stacking and various other techniques – learning how to use my equipment properly! I still have a lot to learn, but I'm happy with my first 'proper' image of the Orion Nebula (above). I took it on 9 January from my cold back garden with a Sky-Watcher 200P telescope and a modified Sony Bridge camera, capturing three frames (30" exposures at ISO 500) and three darks, stacked in DeepSkyStacker and processed in GIMP. The best advice I can give is to spend time getting the polar alignment right; it really is so important!

Simon Franklin, Leeds

Question of distance

This was posed by our child and I thought it was an excellent question: what is the farthest thing that can be seen unaided with the average human eye. I guess it's a galaxy or cluster of galaxies somewhere? How far away is it?

Andrew Pate, via email

You're right Andrew, the farthest object most of us can see with the naked eye is the Andromeda Galaxy, M31, an incredible

2.5 million lightyears away. In dark skies it will look like a hazy patch. Some keen-eyed stargazers have also reported seeing the 2.7-million-lightyear-distant Triangulum Galaxy unaided, though this is a much trickier target needing the darkest skies. ***– Ed.***

A Mars view

Stuart Atkinson's article on stargazing from Mars ('The Red Planet's Sky at Night', February 2021 issue) had me imagining myself standing on the Red Planet, gazing into the heavens. However, I do not think Stuart need worry too much about the difficulties of using a telescope while wearing a space helmet or finding a suitable camera for astrophotography on Mars. *BBC Sky at Night Magazine* has reviewed the Stellina telescope and the Unistellar eVscope, which both feature a scope and camera sensor combined, and which allow the observer to view and image objects on a phone. With scopes like these I see a future that will open up astronomy to many more enthusiasts.

Thankfully, I don't need to wear a space helmet, only a face mask when I go shopping! But I do wear spectacles, so for me moving away from an eyepiece to a screen is a welcome development. I'm certain that, by 2061 an amateur astronomer on Mars will have no trouble taking an award-winning shot of Halley's Comet as it passes Earth.

Bryan Moiser, York

NLCs on Mars

Colour skies?

I have been a *BBC Sky at Night Magazine* reader and watcher for many years and enjoy both greatly, but I have a question about the pictures used in articles on Mars. When talking about the atmosphere, why do you have a picture in black and white showing dark skies and white cloud, such as the image of Martian noctilucent clouds in Stuart Atkinson's feature? ▸

ON FACEBOOK

WE ASKED: If you could holiday anywhere in the Solar System, where would you go?

Stuart Glenwright I'd go on a Kuiper Belt trans-Neptunian object tour. There are so many incredible objects out there and I could do some fascinating science while exploring! There's definitely a photo opportunity for a selfie in the Sputnik Planitia on Pluto. When do we go?

Simon Fletcher The Moon. I'd stay at the Tranquility Hotel, where I could watch Earth rise from my window and take a tour of the historic Apollo landing sites. Next I would visit a region of permanent night to enjoy the panorama of the stars.

Andy Machin I'd take a lucky dip, as any space trip would be out of this world, literally.

Nomis Bennett I'd visit one of Saturn's moons to check out those rings up close

Decky Hayes I would go to Mars because I love chocolate!

Bob Kelly I'd go to Iapetus, Saturn's two-toned moon to get a great view of the rings. The other major moons are in the plane of the rings, so I'd see them edge-on if I picked one of them.

Marc Gravett Pluto, for all its majesty.

Niall Donovan Mars, to show Elon who the real spaceman is.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I have a Stella Wi-Fi adaptor connected to a Meade 14-inch LX200 ACF. I would also like to hook up an eyepiece camera but can't run a cable all the way to my house. Can you suggest any solutions to the problem?

KEVIN BOYNE

▲ **A BT Broadband Extender Kit 600 will ease PC connectivity**

An eyepiece camera usually has a USB connection, but USB cables have a limited length before the signal becomes unreliable. However, this range can be increased considerably by using a USB over Ethernet extender. These extenders comprise two adaptors, one with a female USB socket for the camera and one with a male USB plug that you would connect to your PC, and each have an RJ45 Ethernet port. Your PC's location adds an additional level of complexity, but in theory you could bridge the distance through your home using a Wi-Fi extender like the BT Broadband Extender Kit 600 or TP-Link AV600, which allows both Ethernet and Wi-Fi connections.

A more proven system needs a second PC in the observatory, controlled over the network and using remote access software like PC Anywhere or Windows Remote Desktop if you have Windows 10 Pro or better (not the 'Home' version) on which you could view images remotely. For both options you need to run a CAT5 Ethernet cable from your observatory to your house.

Steve's top tip

Are binoculars good for beginners?

Beginners often ask what their first budget-priced telescope should be, but there is a strong argument for buying a pair of binoculars first: you only have to look at our 'Binocular Tour' (page 54) to see the range of objects that you can observe with a pair. Even simple binoculars will open up a world of interesting observations for you and a pair of 10x50s would be an excellent choice for your first instrument. 10x50 binoculars have the advantage of being hand-holdable, as well as being easily transportable. As a bonus, they are also suitable for observing sports or wildlife, making them excellent value for money by ensuring that you will use them regularly.

Steve Richards is a keen astro imager and an astronomy equipment expert

WWW.BT.COM

BBC Sky at Night MAGAZINE | IMMEDIATE MEDIA Co

BBC Sky at Night Magazine is published by Immediate Media Company Bristol Limited under licence from BBC Studios, which helps fund new BBC programmes.

SUBSCRIPTION RATES
Annual subscription rates (inc. P&P): UK cheque/credit card £62.40; Europe & Eire Airmail £75; rest of world airmail £85. To order, call 03330 162119 (UK); overseas +44 (0)1604 973727

ipso Regulated

We abide by IPSO's rules and regulations. To give feedback about our magazines, please visit immediate.co.uk, email **editorialcomplaints@immediate.co.uk** or write to The Editor, *BBC Sky at Night Magazine*, Immediate Media Co., Eagle House, Colston Avenue, Bristol, BS1 1EN.

Audit Bureau of Circulations
17,385 (combined; Jan–Dec 2019)

ISSN 1745-9869

▸ (See 'The Red Planet's Sky at Night', Feb 2021 issue, page 66.) It is the same on the NASA site; why do they show black and white pictures of superb scenery with the sky in the top of the shot? Why build a rover costing billions of dollars only to take black and white pictures? Do NASA and your magazine want to hide the fact that the Martian skyline is blue like on Earth? When I look at NASA photos for the various rover missions the sky in many shots is blue. All I want is colour pictures of our neighbour to highlight its beauty; red or blue sky, I want to see it as it is.
Jason Trussell, Essex

We're certainly not hiding anything, Jason! Mars rovers are operating 180 million km from Earth where sunlight isn't as bright, and where the atmosphere is primarily carbon dioxide (rather than nitrogen and oxygen on Earth) and contains more dust. If colour images look monochrome it's due to these factors. Martian sunsets do look blue close to the horizon, but the sky on Mars is generally a butterscotch colour because of all the dust. Some rovers' cameras are colour, some are black and white with filters, and some have both. Black and white cameras are better resolution than colour cameras, so if the mission team wants detail rather than colour, black and white images are better quality and quicker to obtain. ***– Ed.***

Instagram

sambinding • 30 December 2021

Time to Burrow down. From a night up Burrow Mump hunting for galaxies with @tjphillips76 – see if you can spot Jupiter making its way through the open door… @astrobritain @uk.astroscapes @bbcskyatnightmag #milkyway #somerset #photosofbritain #astrophotography #bbcskyatnightmag #stayandwander #sonyalpha

SOCIETY IN FOCUS

AstroBoost is a project engaging and educating the public about the James Webb Space Telescope (JWST) with the help of a group of astronomy societies across the UK, including **Norwich Astronomical Society**.

The project is managed by science communicator Dr Jenny Shipway and is delivered by the Webb UK campaign and funded by the STFC. Its aim is to harness the knowledge and skills of astronomical societies to engage people across the UK with the JWST's cutting-edge technology. In March 2020 members from societies were to attend a training session at the Royal Observatory Edinburgh, but due to the pandemic, it was held in November, through online video-conferencing.

The training session included presentations on JWST's design, aims and objectives and a focus on its Mid-Infrared Instrument. A kit supplied to each astro society included an infrared camera, thermal blanket, heat pad and gold cardboard hexagon segments that can be assembled to show the design of its 6.5m-wide mirror. When assembled, the hexagon segments represent the size of a single mirror on the actual telescope.

▲ Dr Jenny Shipway hosts a pre-COVID-19 AstroBoost session about the JWST

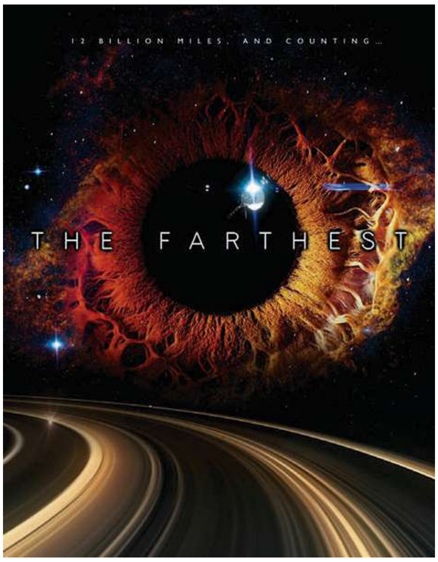
Norwich Astronomical Society is honoured to be part of this programme and we look forward to when we can engage public groups and run events sharing knowledge of this exciting project.
Andrew Sutkowski, membership secretary, Norwich Astronomical Society
▸ www.norwichastro.org.uk

COVID-19

Online and socially distanced events taking place this month

We pick the best live and virtual astronomy events and resources this month

WHAT'S ONLINE



DOCUMENTARY

The Farthest

An excellent, witty and moving celebration of that monument to human achievement: the two Voyager missions, launched in 1977 and to this day travelling ever onwards into interstellar space, featuring fascinating interviews with many of those who have dedicated their lives to the project. **On Amazon Prime**

CITIZEN SCIENCE

Bursts from Space

You could be the first person to hunt down a 'furbie', aka Fast Radio Burst or 'FRB', if you join this new project. Using weekly data from the CHIME (Canadian Hydrogen Intensity Mapping Experiment) telescope in British Columbia, you'll be tasked with sifting potential FRBs from human-made signals. **bit.ly/38EuaDJ**

Globe at Night

Join the battle against light pollution in this international citizen science project to measure night sky brightness. Submit your observations using the Globe at Night app on your laptop or mobile. This month's target constellations are Orion and Leo. **www.globeatnight.org**

PICK OF THE MONTH

▲ Podcast presenters (from left) Matt Russell and Jamie Franklin lead the weekly science show

The Interplanetary Podcast

Upbeat podcast on all things astronomy, cosmology and space exploration

Running since 2016 and clocking up over 200 episodes and half a million downloads to date, The Interplanetary Podcast is an excellent weekly show for anyone even remotely interested in space.

Hosted by Matthew Russell, Jamie Franklin, Julio Aprea, Chris Carney and Harriet Brettle – a mix of space enthusiasts and industry experts – it manages to pull off that tricky balance between geek-friendly, informed science and an accessible, light delivery style.

Top space experts, including presenter Brian Cox, theoretical physicist Jim Al-Khalili and former astronaut Kathy Sullivan and astronaut Matthias Maurer are among the recent interviewees, plus there's book chat and news on the latest research, missions and launches. **www.interplanetary.org.uk**

APP

Stellarium Mobile Plus

Carry this desktop favourite in your pocket, loaded with super-useful features, an intuitive interface, a database of millions of objects, daily target tips, live AR mode and even the ability to drive compatible Go-To telescopes. It costs £9.99 for iPhone and is free for Android.

PODCAST

The Actual Astronomy Podcast

For some hands-on, practical observing-focused chat, check out this podcast from laid-back Canadian amateur astronomers Chris and Shane. **On various podcast platforms**

RADIO

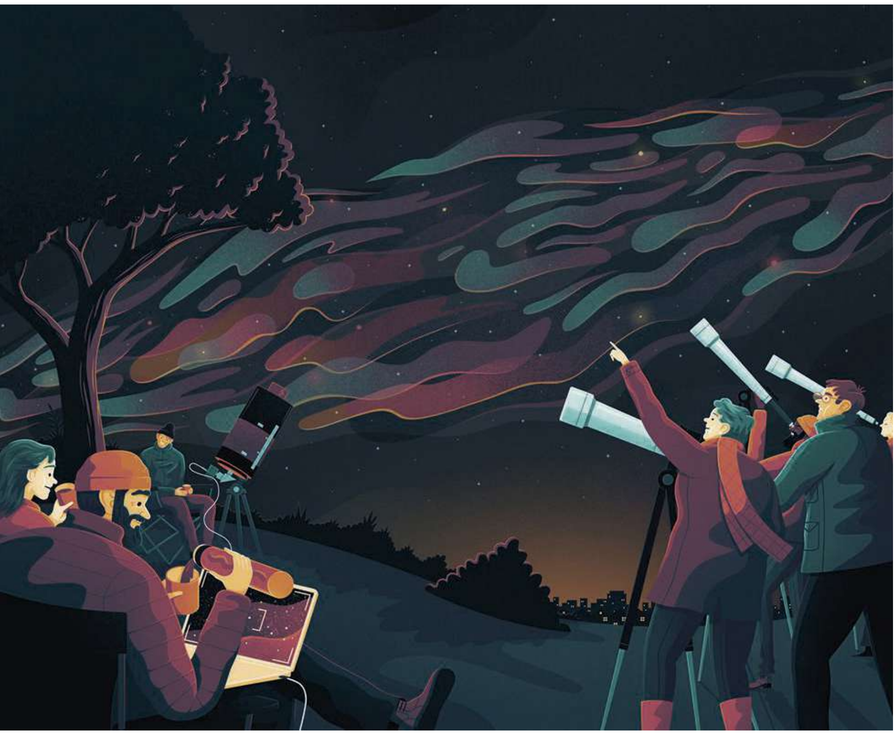
In Our Time – Eclipses

Physics professors Lucy Green and Frank Close and public astronomer Carolin Crawford discuss our historical understanding of eclipses with Melvyn Bragg, taking an in-depth look at the scientific advances gained from studying them . **www.bbc.co.uk/sounds/play/m000qmnj**

FIELD OF VIEW

Same sky, different tactics

Ron Brecher on the nocturnal behaviour of imagers and eyepiece astronomers



Ron Brecher images deep-sky objects from his observatory in Ontario, Canada, while simultaneously observing through the eyepiece from his driveway. His images, articles and more are available at **astrodoc.ca**

For nearly a quarter century I've been studying astronomers – including myself – 'in the wild'. I've noticed some interesting differences between my fellow astronomers, depending on whether they are catching photons with their eyes, a camera, or both.

Let's start with who's talking and when. Eyepiece astronomers can be downright chatty while setting up their relatively simple equipment (I'll get to that in a moment). But once the serious observing starts, they tend to go quiet. They often observe in small groups and speak in whispers, occasionally consulting a star chart with a dim red flashlight. Imagers are exactly the reverse. Although quiet during setup, they can be downright boisterous while the cameras do the observing. They may hang out in large groups. Or they may just go to sleep…

With relatively simple equipment, visual astronomers don't need much power. One small battery for my red dot finder is enough for many nights of observing with my 10-inch (254mm) Dobsonian telescope. For my 20-inch (508mm) Dobsonian I also use a 9V battery for a fan to cool the primary mirror, but that's about it. When I'm doing astrophotograpy it's another story: I need power for a mount, two cooled cameras, a guidescope, two electronic focusers, a PC and two dew heaters. And all that gear means much more can go wrong too; I've never had to quit looking through the eyepiece because of an unplanned Windows software update!

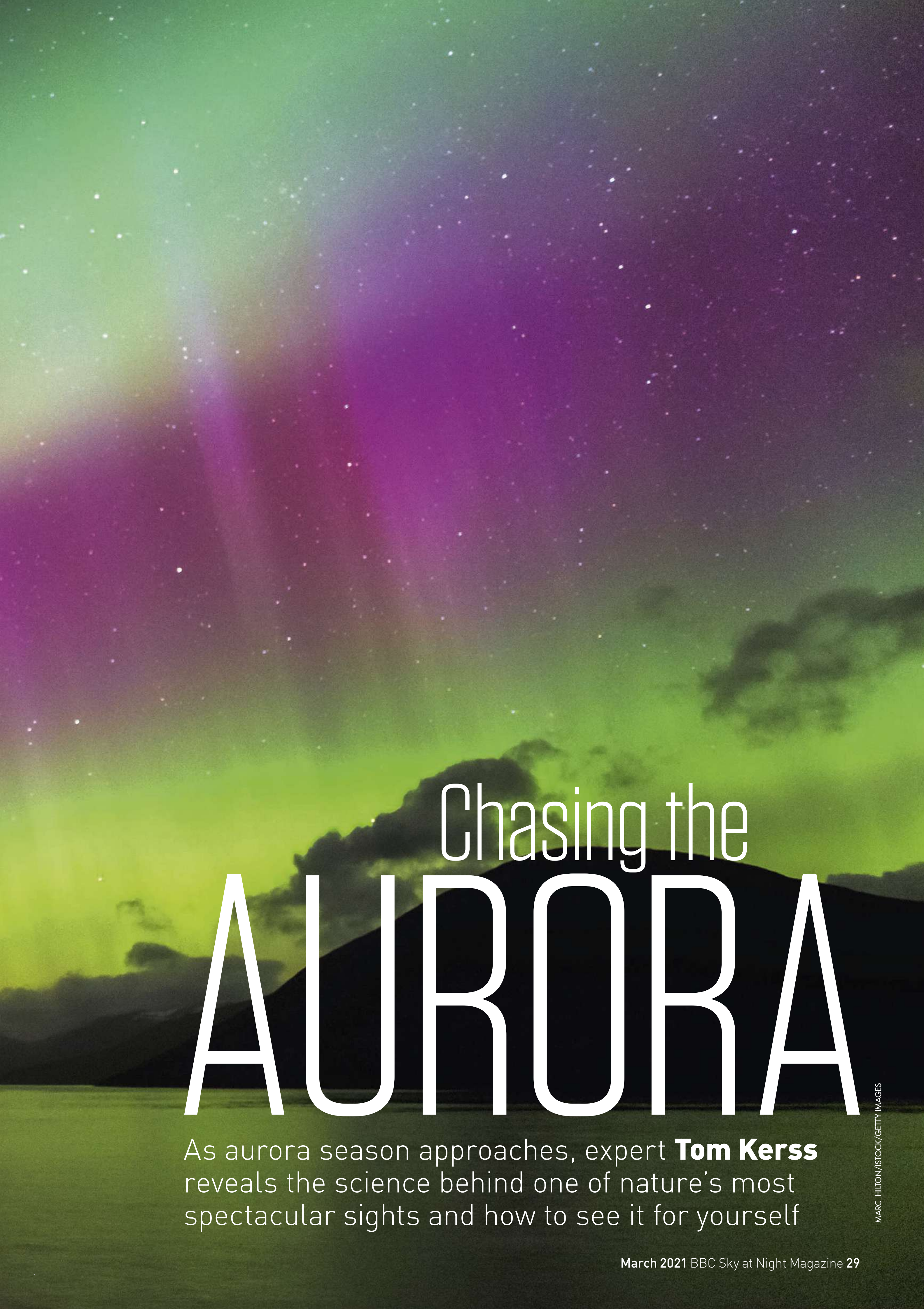
However, there are some conditions that put a damper on a visual observing session, the most important being extreme cold. In my locale, winter observing tends to be brief, even for the hardiest astronomers. Cold doesn't have to affect imaging, since most imagers can find shelter while their equipment carries on. Excessive heat and intermittent clouds are the opposite. Clouds at the wrong place and time can cause the failure of automated focusing or autoguiding, which can stop an imaging run in its tracks. On very warm nights, camera sensors and optics can be harder to cool and stabilise for imaging. Meanwhile, the visual astronomers are in T-shirts, happily pointing their scopes between the clouds at their favourite objects.

Another interesting dichotomy between visual and imaging astronomers is the length of the target list for a given night. I usually have a slew (pardon the pun) of targets in my visual observing plan; I once viewed 15 globular clusters in the constellations of Ophiuchus, the Serpent Bearer, and Sagittarius, the Archer over a three-hour period. As an imager, I think in terms of nights-per-target rather than targets-per-night, having learned that my best photos come from the patient acquisition of photons over multiple nights.

We're fortunate that we can choose to enjoy visual astronomy, astro imaging, or both. For me, nothing can replicate the experience of photons hitting my retina and activating my brain after a trip across space and time, and into my scope. But images reveal so much more detail and colour, and can be enjoyed by people who will never climb a ladder in the dark at –20°C, or whose vision won't let them see well at the eyepiece. After considering everything, I'm going to keep doing both – usually at the same time!

JACOB STEAD/ HTTPS://JACOBSTEAD.COM

Awe-inspiring display: a spectacular view of the Northern Lights awash with colours, as captured from Garve in the Scottish Highlands



Chasing the AURORA

As aurora season approaches, expert **Tom Kerss** reveals the science behind one of nature's most spectacular sights and how to see it for yourself

MARC_HILTON/ISTOCK/GETTY IMAGES

Back in September 2008, *Absolutely Fabulous* star Joanna Lumley took BBC viewers on a journey to witness the Northern Lights. Inspired by a favourite story from her childhood, Lumley had been fascinated by the phenomenon for decades and longed to see it, finally embarking on her own expedition to the hyperborean extremes of Norway. The documentary, *Joanna Lumley in the Land of the Northern Lights*, delivered on its promise with an emotional climax, complemented by beautiful time-lapse photography that lingered in the minds of many would-be aurora chasers. In my years of accompanying Brits to northern climes to see the Lights, I've heard many accounts of watching that documentary, the most memorable aspect being Lumley's own touching reaction. After long anticipation, those people have then encountered the Lights themselves, their reactions a perfect reflection of the one that had motivated them.

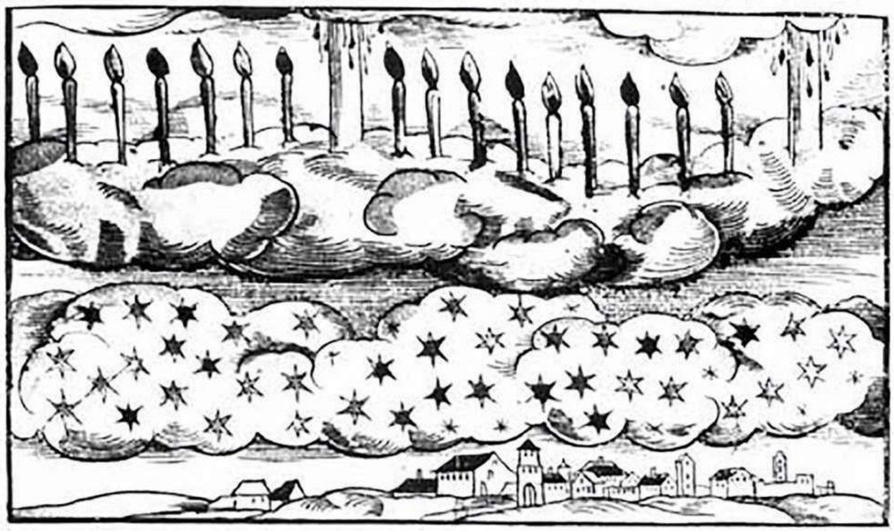
There's something universal about the awe we feel in the presence of such a strange and wonderful encounter. My first sight of a dynamic auroral display high overhead was so spellbinding that I unthinkingly walked forward in awe, stepping onto a frozen stream and plunging one foot through the ice. Needless to say, that brought me back to Earth swiftly! But soon I was entirely enthralled by the sky again, the cold merely a background sensation unable to break my attention. It is a truly arresting phenomenon that is entirely unlike anything else you will ever see.

Top of the list

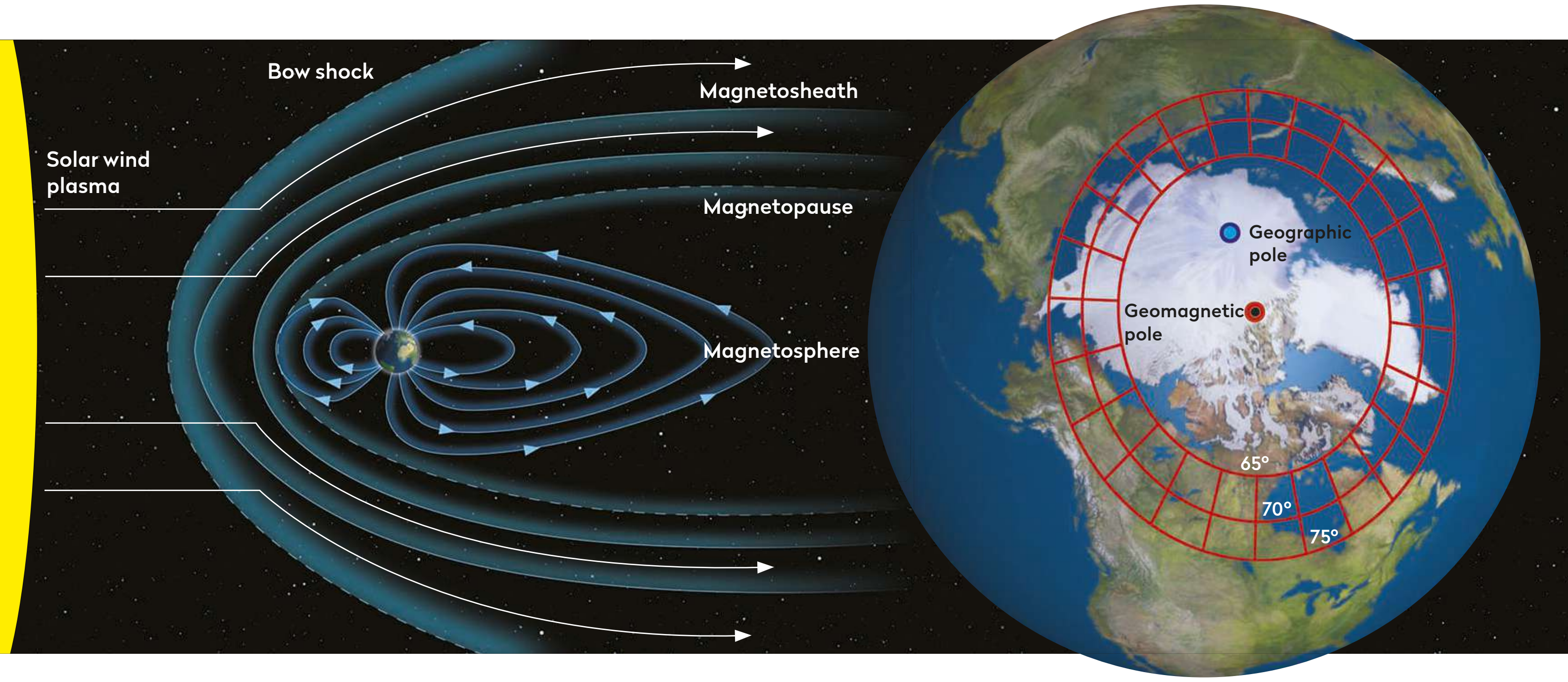
It's not surprising that the internet's largest tracker of 'bucket list' suggestions ranks seeing the Northern Lights at the number one spot, and by a wide margin. Word gets around, and those who have been fortunate enough to witness a striking display are at once both excited to tell their friends and unable to find sufficient language to do it justice. "You just have to see it for yourself".

▲ A familiar sight: the beautiful aurora displays appear regularly in countries like Norway between autumn and spring

Of course, not everyone needs to travel to see the Northern Lights regularly. For a few million people in northerly parts of the globe they're a familiar, nightly occurrence between autumn and spring. There is no exact record of their discovery – the earliest Arctic settlements date back over 1,000 years – but there are notable mentions of historic sightings in regions where they seldom appear; for example, ancient Greece and China. This is only possible under exceptional circumstances, perhaps only once on a timescale of many generations. The sight of the aurora must have been inexplicable for early witnesses and hard to believe, if not sheer legend, for those they tried to explain it to. Galileo, who investigated reports with great interest, proposed that they were formed by sunlight reflected from the atmosphere. In 1619,



▲ Historic sighting: a drawing of the Northern Lights, as viewed from Bohemia on 12 January 1570, portrays the phenomenon as candles in the sky



he coined the term 'aurora borealis', from Latin: 'Dawn of the North'. In fact, 'Northern Lights' is actually the much older name. In the ancient Icelandic language they are called '*Norðurljós*' – literally 'North Lights'. The first serious scientific proposal for their origin did not arrive until as recently as the end of the 19th century, when Norwegian physicist Kristian Birkeland replicated them in the laboratory. Using a magnetised sphere to represent Earth, he demonstrated that glowing ovals appear around the magnetic poles when gas is excited by high energy electrons.

Under the Sun's influence

The aurorae are a continuous reminder of our planet's unbroken connection with its parent star. What we tend to imagine as empty space in the Solar System is actually flooded with solar radiation: protons and electrons streaming away from the Sun's atmosphere at an average speed of 1.6 million kilometres per hour. Enormous, high-energy events such as coronal mass ejections (CMEs) also release colossal quantities of solar plasma and magnetic energy into the planetary region. Far from being smooth in distribution, the solar wind is lumpy, its influence on Earth ever-changing. The study of space weather enables us to forecast the circumstances of the Northern Lights, as solar wind particles are captured by Earth's magnetic field and accelerated towards the magnetic poles. Diving into the atmosphere, they strike gas atoms and molecules, ionising them and resulting in the release of different colours of light. Radio waves are also released and, under specific conditions, a crackling sound may be produced. The strength and motion of the Northern Lights varies sensitively with both the intensity of the solar wind and the stability of Earth's magnetic environment. When a pocket of solar magnetic energy, released during a CME, strikes ▸

▲ Cause and effect: Left: as the solar wind hits Earth's magnetic field, small particles are captured and accelerated towards the magnetic poles Right: the process creates an auroral zone – in this case the northern auroral oval – where colourful displays will occur in an area centred on Earth's magnetic poles

Forecasting the aurora

How do scientists predict when and where the Northern Lights will appear?

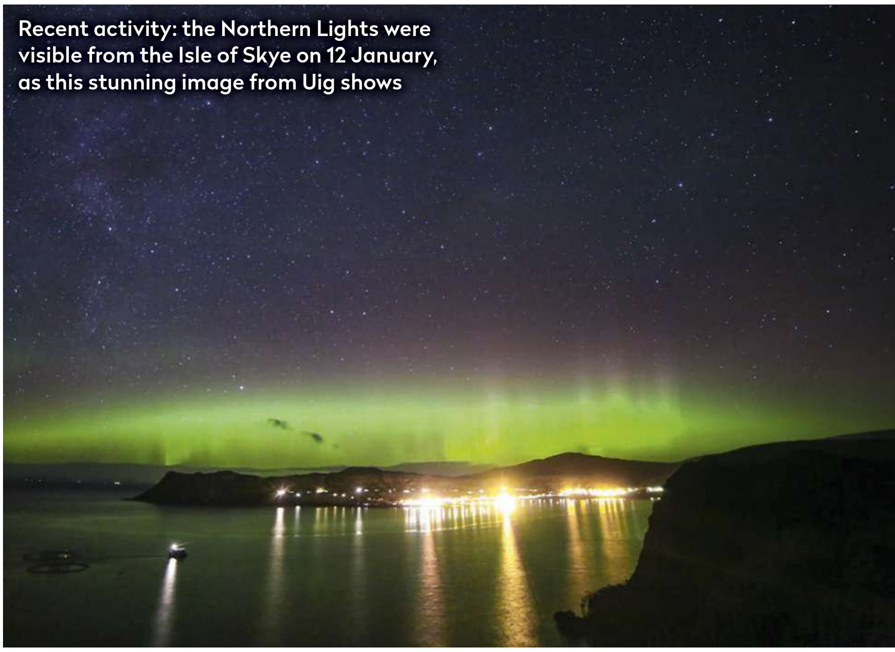
The University of Lancashire's AuroraWatch (**aurorawatch.lancs.ac.uk**) offers free alerts for potential sightings in the UK, and many excellent space weather websites provide an outlook on the auroral activity over the coming days. The University of Alaska Fairbanks Geophysical Institute (**gi.alaska.edu/monitors/aurora-forecast**) monitors solar activity with a predictive timescale of several weeks, with dedicated predictions for Europe. Researchers calculate a Kp-number (derived from the Planetarische Kennziffer or 'planetary index number'), which ranges from 0-9, describing auroral intensity. When a geomagnetic storm arrives, the Kp-number reaches or exceeds 5. Typically, the number is around 2, which is relatively calm.

With a fleet of remote sensing spacecraft, such as NASA's Solar Dynamics Observatory (SDO), Solar and Heliospheric Observatory (SOHO) and Solar Terrestrial Relations Observatory (STEREO), space weather scientists can monitor perturbations in the solar wind and predict their arrival at Earth, and new missions like the ESA/NASA Solar Orbiter will help improve forecasting for our aurora trips in years to come.

NASA's Solar Dynamics Orbiter (SDO) helps scientists to monitor the solar wind

ILLUSTRATION

▸ Earth, a geomagnetic storm occurs, expanding the size of the auroral ovals and bringing the Northern Lights further south. At such times, they can cover the sky as seen in the Arctic and break clear from the horizon for observers in Scotland, becoming visible across much of the northern UK.



Recent activity: the Northern Lights were visible from the Isle of Skye on 12 January, as this stunning image from Uig shows

Colours of wonder

The most prominent auroral colour is green, released by excited oxygen atoms between 100–150km above ground; our eyes are sensitive to this colour, even in low light. Dynamic displays of rippling, dancing curtains often have a pinkish edge at the bottom and for fleeting moments, the colour can be very prominent against the green above it. This pink colour results from a mix of blue and red light emitted by molecular nitrogen at lower altitudes. Cameras, without the colour bias of the dark-adapted eye, can draw out an extraordinary range of hues from a bright display.

At high altitudes, atomic oxygen creates a deep red, almost crimson fade from the top of an auroral curtain to stars above it. The mixing of colour can also result in yellows and blues appearing with varying degrees of clarity. Meanwhile, the curtains may hang stoically, or dance playfully. Sometimes they divide or merge in line with the 'sheets' in Earth's magnetic field. During an intense display you may be lucky and find yourself looking straight up into an auroral corona at the zenith, making it appear as though it is enveloping you.

How to see the aurora

Top tips on how to spot a spectacular auroral display for yourself

▸ Make a decision on your aurora-chasing destination and stick with it. Travel close to new Moon and prepare to go looking every night during your trip, even if the forecast is cloudy.

▸ Use local weather services to choose a location with the highest chance of clear sky throughout the night.

▸ Research your viewing site and be prepared to spend some hours there. You should aim to stay out until at least 01:00 to 02:00

▸ Find a spot away from a road to avoid interference from vehicle headlights.

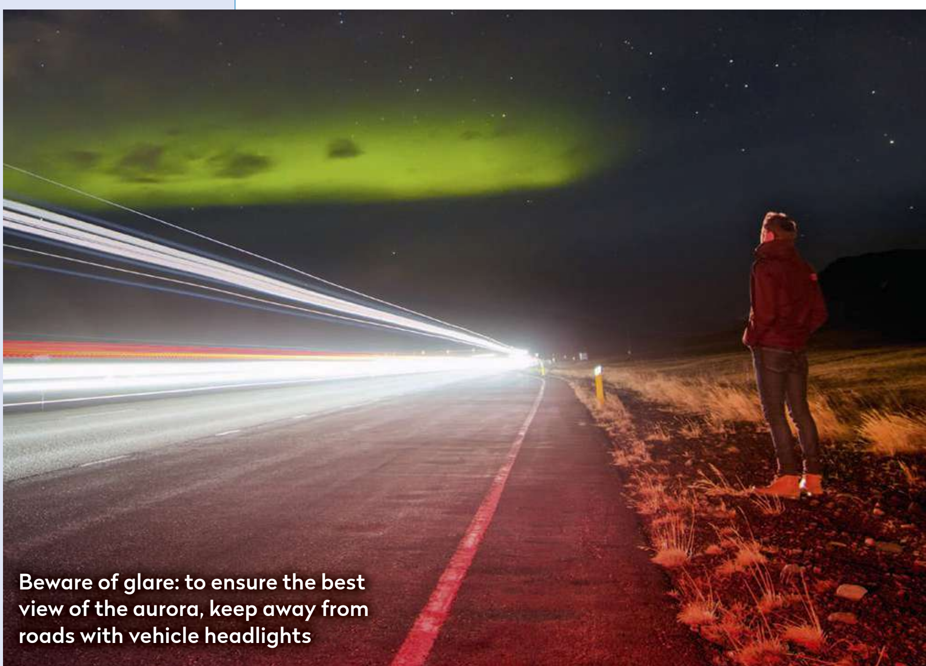
▸ Take care driving on unfamiliar terrain, particularly in the Arctic wilderness! If renting a car, consider something suitable for rough roads.

▸ You don't need any equipment, but if you're planning to photograph the aurora, set up your camera before stepping into the cold. Turn off your car's headlights and any interior lights.

▸ If it's windy, park your car in such a way that you can use it as a windbreak while keeping a clear view of the north.

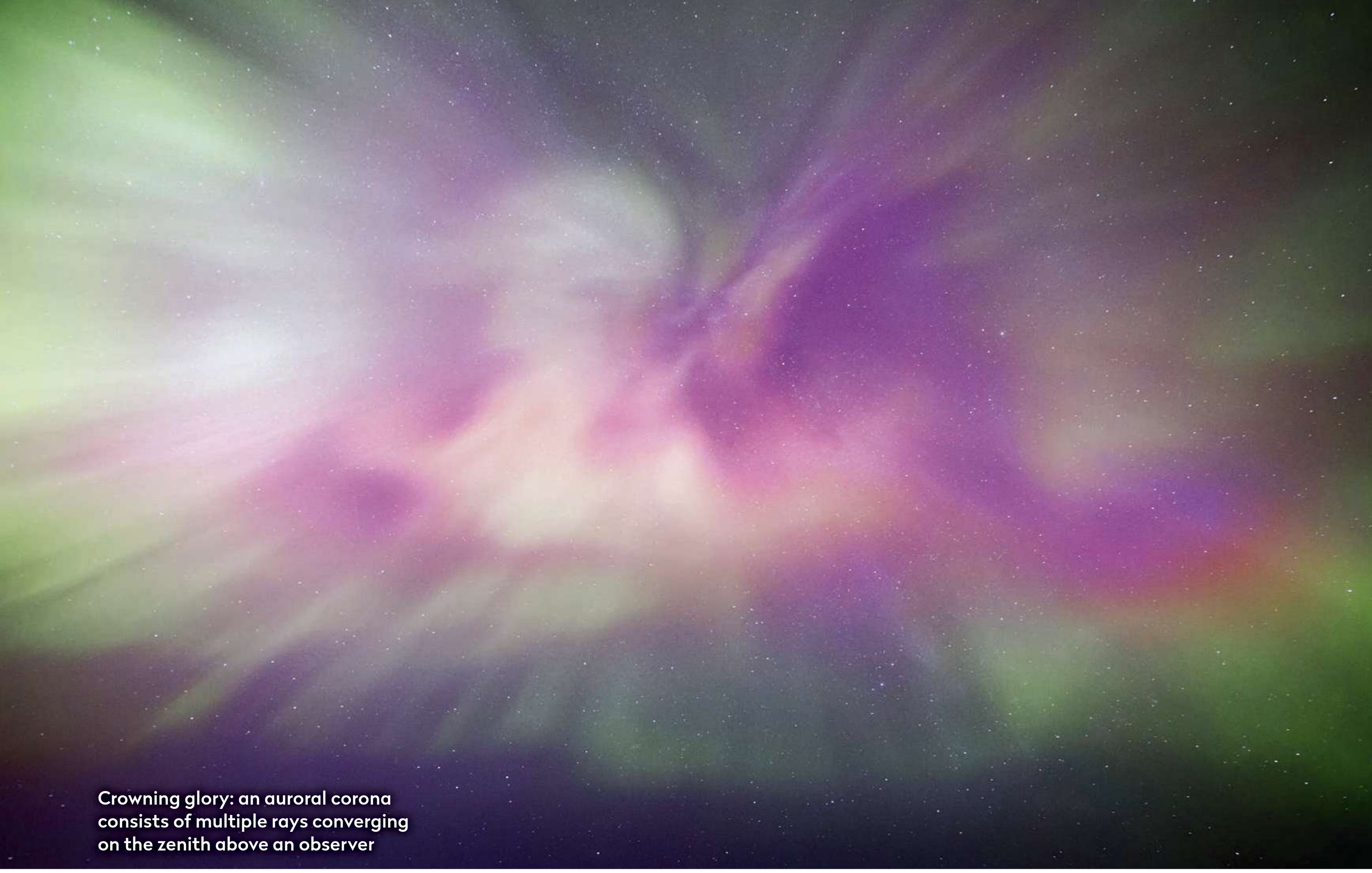
▸ Scan the northern horizon. Look for diffuse, cloud-like patches of light. Most displays are gentle to begin with. The luminosity and faint green colour of a brightening auroral display are very distinct.

▸ Keep watching until the display picks up in energy. You'll see more movement and colour as auroral curtains ripple across the sky. Use a wide aperture and take exposures of a few seconds with your camera to capture the colours.



Beware of glare: to ensure the best view of the aurora, keep away from roads with vehicle headlights

MATT DEAMER/MATT2901/TWITTER, TOM KERSS, EERIK/ISTOCK/ GETTY IMAGES, ULRICHBEINERT/ISTOCK/GETTY IMAGES



Crowning glory: an auroral corona consists of multiple rays converging on the zenith above an observer

▲ Up in Lights: dedicated flights take aurora-chasers to the Arctic Circle to get close-up views of a display

There is a common misconception that the aurorae are only visible at a peak of the solar cycle, which occurs once every 11 years. Given that we entered Solar Cycle 25 last year, and maximum solar activity is forecast for 2025, this would mean waiting quite some time. Fortunately, this isn't necessary; while increased solar activity does indeed provide more opportunities for explosive auroral displays, they can still be seen in quieter years with reasonable frequency.

For those new to aurora chasing, mid-September and October are particularly welcoming times to make your first expedition. Between November and January, the extreme cold of northern nights can be a real challenge. February and March are a little kinder and typically less expensive months to travel. During the northern summer months, many places at high northern latitudes experience short hours of night, or no real night at all, so the sky does not get sufficiently dark enough for the Northern Lights to become visible.

Many excellent aurora-chasing destinations are within reach of the UK: Iceland, Norway, Sweden and Finland are all famed for their access to the Northern Lights on solid ground, while cruises and short flights can take you up to the Arctic Circle on a dedicated trip. If you'd prefer to stay in the UK, consider an aurora-chasing trip to Inverness. I spent some of my childhood near Lossiemouth, where the Lights can be glimpsed over the North Sea. On rare occasions, they can be seen as far south as North Wales, giving millions of Britons the opportunity to experience the phenomenon without needing to travel too far.

Successful aurora-chasing is a matter of picking the right time and place, but luck will always play a part, just as with any other form of astronomy. However, no matter the conditions, your first view of this magnificent natural wonder will always stay with you. Neither freezing cold nor partial cloud can spoil it. Almost everyone I've introduced to the Northern Lights initially expected to relive Joanna Lumley's televised experience, but she was luckier than most get. However, what they eventually saw was infinitely better: the real thing. It's worth the adventure!

Tom Kerss is an astronomer, science communicator and author of *The Northern Lights*, due for release in September 2021. For details of his podcasts see **https://starsigns.live**

Precious cargo: OSIRIS-REx departs from asteroid Bennu to begin its long journey home

ILLUSTRATION

NASA/GODDARD/UNIVERSITY OF ARIZONA, NASA'S GODDARD SPACE FLIGHT CENTER CONCEPTUAL IMAGE LAB

Homeward bound from BENNU

As the OSIRIS-REx spacecraft prepares to start its long trip back to Earth, **Will Gater** recounts the thrilling inside story of the mission's asteroid sampling and what its captured cargo of space rocks could tell us

Going slow: OSIRIS-REx fires its thrusters to ease its descent to the surface of asteroid Bennu in October 2020

As the first image came back from OSIRIS-REx on 22 October 2020, everything looked pretty much as expected to the mission's principal investigator, Professor Dante Lauretta. It was the pictures that were received next – from the robotic explorer's 'SamCam' camera – that caused the concern.

"I don't like this," said Lauretta, turning to systems engineer Estelle Church who stood beside him in the spacecraft operations centre at Lockheed Martin's site in Littleton, Colorado.

"I don't like it either," Lauretta recalls her saying.

Lauretta quickly picked up the phone to his colleague, OSIRIS-REx's project manager, Rich Burns.

"Are you looking at the images from SamCam?," asked Lauretta. "You need to get down here right away!"

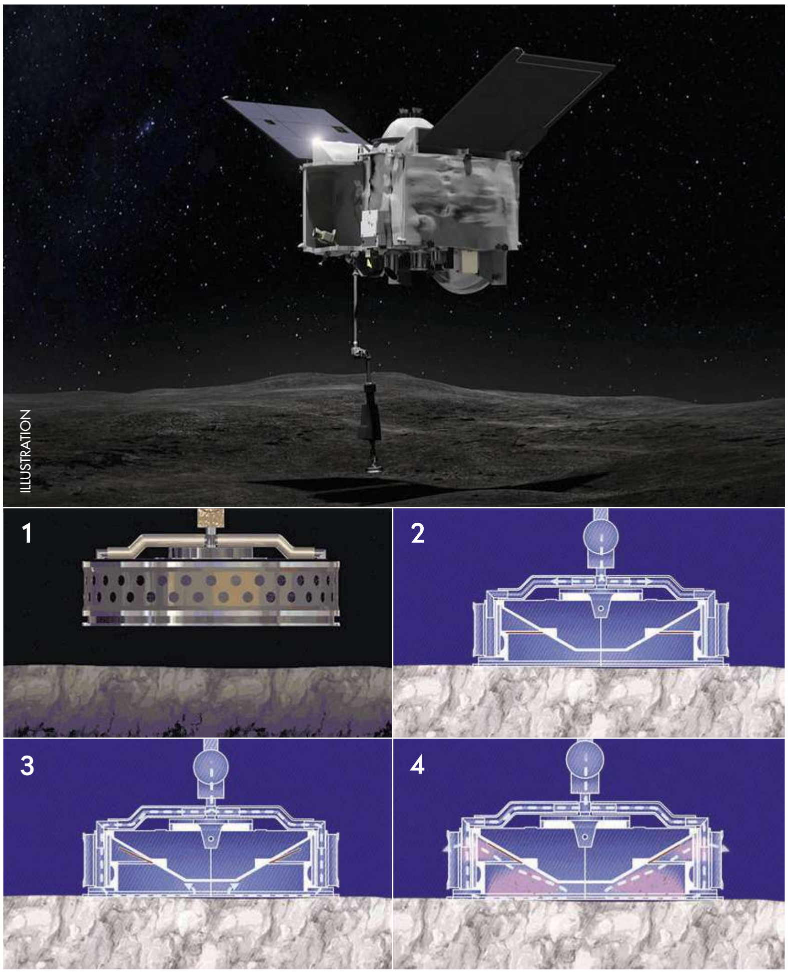
Just days before, the OSIRIS-REx spacecraft had completed the most thrilling phase of its mission – a sampling of the surface of near-Earth asteroid Bennu. That manoeuvre marked the crescendo of a scientific investigation years in the making, yet the mission still to complete a crucial part of its itinerary: getting home. While the OSIRIS-REx team will spend the coming months preparing for the engine burn that will send it Earthwards, emotions are still running high from what's transpired so far.

Finding a target

After travelling across the inner Solar System to Bennu, OSIRIS-REx – which launched in 2016 – had carried out a detailed two year-long reconnaissance and study of its rocky target. From the outset Bennu showed that it was holding more secrets than many might have imagined. Researchers had expected the surface of the asteroid to be largely covered in small, centimetre-sized pieces of material. Instead, images captured by the spacecraft upon its arrival showed a body strewn with enormous boulders and large rocks.

Eventually, after careful analysis, the mission team identified a patch on Bennu that was a little less rugged than its surroundings; the crater, nicknamed 'Nightingale', would be the site of the mission's key objective. It was at this spot that the spacecraft would dive down to collect material that would be later whisked home to Earth.

At the heart of the procedure was a collector mounted to an articulated robotic arm extending out from the main body of the spacecraft. This TAGSAM – or Touch-and-Go Sample Acquisition Mechanism – instrument would press into the surface and release a blast of nitrogen gas, forcing a cloud of rocky matter up into a shallow cylindrical compartment.

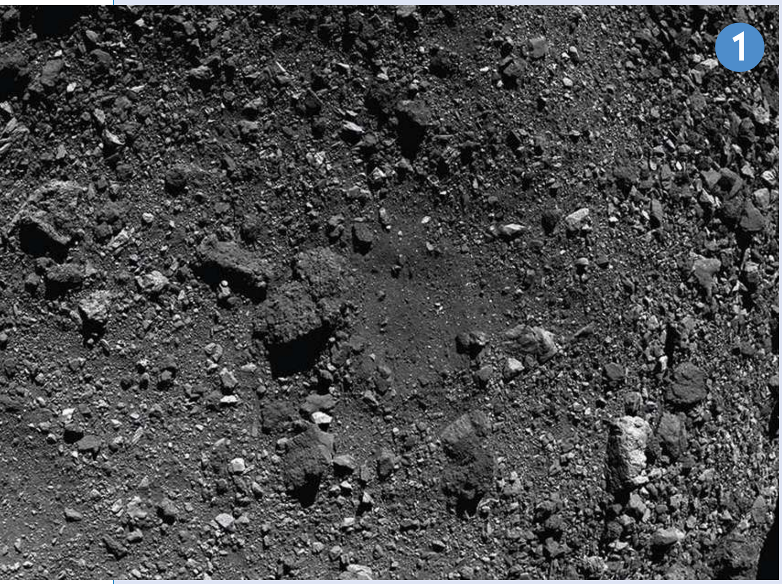


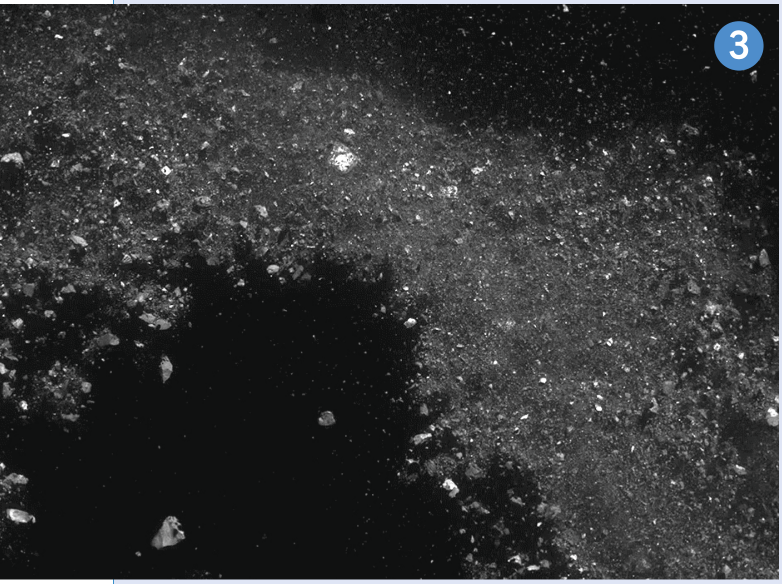
▲ **Taking a sample: TAGSAM (the Touch-and-Go Sample Acquisition Mechanism) at the end of OSIRIS-REx's articulated arm, collected rocks by blasting nitrogen gas onto the asteroid's surface after contact**

NASA'S GODDARD SPACE FLIGHT CENTER CONCEPTUAL IMAGE LAB, NASA'S GODDARD SPACE FLIGHT CENTER, NASA/UNIVERSITY OF ARIZONA/LOCKHEED MARTIN X 4, NASA/GODDARD/UNIVERSITY OF ARIZONA X 3

A swift sampling

Three key moments of OSIRIS-REx's sampling procedure, as seen by two different black and white cameras mounted on the NASA spacecraft





1. The spacecraft is descending to the rock-strewn surface of Bennu in this image from the 'NavCam 2' camera. The sampling site, codenamed 'Nightingale' by the mission team, appears in the centre as an oval area with fewer large boulders.

2. OSIRIS-REx's sampling arm, along with the circular TAGSAM (Touch-and-Go Sample Acquisition Mechanism) device at the far end, can be seen in this SamCam camera image; this frame captures the instant that the TAGSAM collector contacts, and embeds into, the loose rocks on the asteroid's surface.

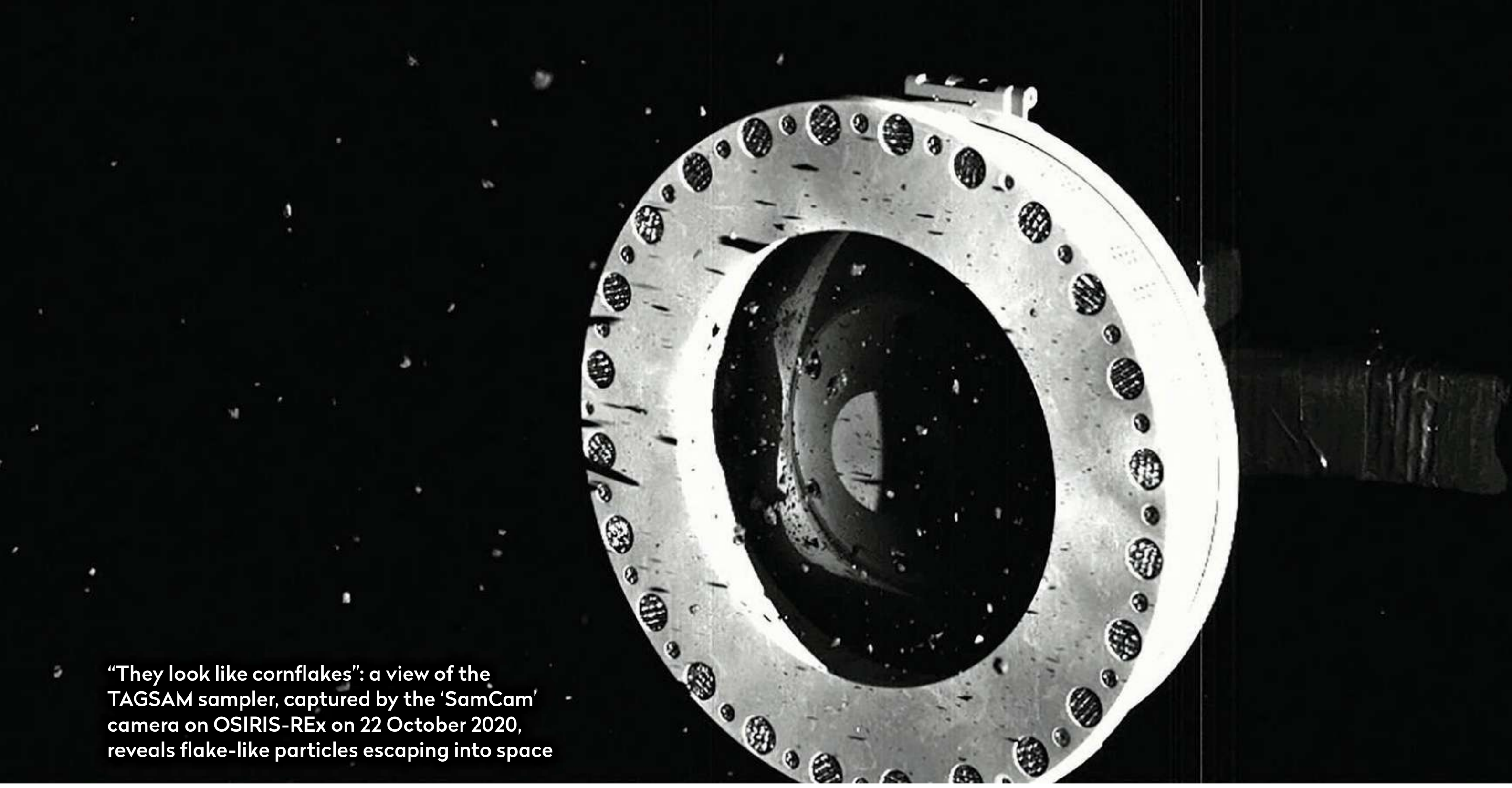
3. The TAGSAM device (not pictured in this view from NavCam 2) has released its blast of nitrogen gas; dense clouds of rocky asteroid regolith are now emanating from the sampling site as the spacecraft pulls away from Bennu.

The sampling on 20 October went exactly to plan, and images returned by OSIRIS-REx of the spectacular operation showed the TAGSAM device embedding into the surface of Bennu and the spacecraft pulling away.

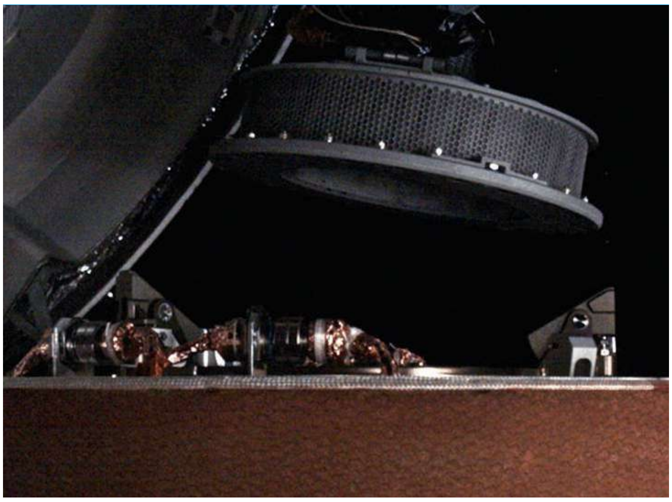
Tension rises

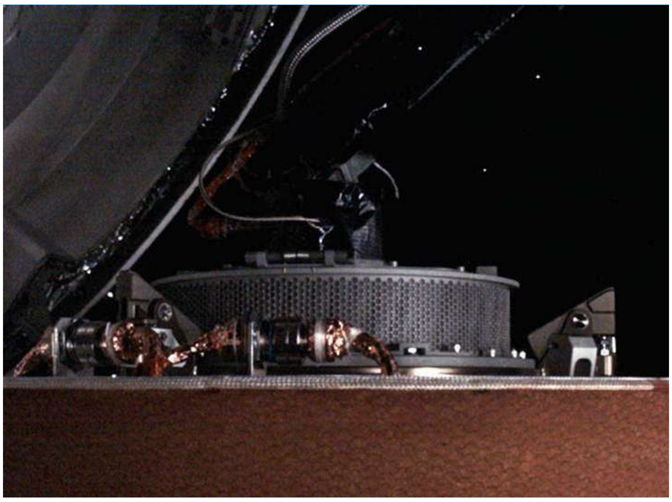
The mission team needed to check that they'd actually caught pieces of the asteroid, though, so a short while later they commanded the craft to capture images at various exposure lengths of the head of the sample collector. It was these images that were now appearing on a large screen in front of Dante Lauretta and his colleagues, causing a chill of consternation.

"As we got to the really long exposure images we could just see these rays emanating from the TAGSAM head," recalls Lauretta. Each 'ray' was the blurred trajectory of a tiny piece of asteroid drifting in front of the camera – somehow the sample that OSIRIS-REx had come so far to capture was escaping. "My heart was breaking because every piece that I ▸



"They look like cornflakes": a view of the TAGSAM sampler, captured by the 'SamCam' camera on OSIRIS-REx on 22 October 2020, reveals flake-like particles escaping into space





▲ Above (left and right): two images of the TAGSAM sample container being stowed on the OSIRIS-REx spacecraft. Particles taken from Bennu are seen escaping in the picture to the right

NASA, NASA/GODDARD/UNIVERSITY OF ARIZONA/LOCKHEED MARTIN, NASA/JPL-CALTECH/ARIZONA STATE UNIV./SPACE SYSTEMS LORAL/PETER RUBIN, JAXA, SOUTHWEST RESEARCH INSTITUTE

▸ saw drifting away, I thought 'that's somebody's PhD thesis that's being lost into space right there'," says Lauretta.

As the team raced to establish how the pieces were getting out of the TAGSAM container, though, a more positive picture of what the collector had snagged began emerging. One of the images returned showed that a 3cm-wide chunk of Bennu was holding open the mylar fabric 'valve' that was supposed to ensconce any sample that had been captured. Further study of the pictures from OSIRIS-REx showed another four rocks – between about one and three centimetres in size – all doing the same thing.

Although they were wedging open the collector's valve and allowing particles to spill out, the scientists were able to conclude – based on assumptions about their density and estimates of their volume – that the five rocks represented some 30g of sample material; and all of it appeared firmly stuck in the collector. For a mission that was tasked with bringing home 60g of asteroid that was a significant proportion of the target.

What's more, the mesh screen that forms the wall of the cylindrical TAGSAM container appeared completely opaque, in stark contrast to identically-composed test images taken before the sampling, which showed sunlight streaming through it. That, the researchers argued, indicated an additional 50g of asteroid material was sitting inside, obscuring the tiny holes in the mesh.

The team were even able to glimpse inside the container in one of the images sent back. "You could actually see past the [mylar] flap and see that there were black grains inside," says Lauretta. "It's about 17 per cent of the total volume of the collector that we can see in there. If it's filling that volume that's about another 300g of sample," he adds.

The ones that got away

All in all, Lauretta and his colleagues believe several hundred grams of material were captured by the TAGSAM device. A total of a hundred or so grams were likely lost, including pieces that escaped when the robotic arm moved to secure the collector inside the sample-return capsule for its journey home – a procedure that was conducted earlier than planned to prevent more of the sample being jettisoned. Yet even the pieces of Bennu that got

Asteroid adventurers

OSIRIS-REx is just one of several current and future missions tasked with exploring the small, irregularly shaped bodies of our Solar System

Strange worlds

In 2024, the Japanese Space Agency (JAXA) and German Aerospace Centre (DLR) are planning to send a mission to the object responsible for the Geminid meteor shower. The Destiny+ spacecraft will rendezvous with the asteroid Phaethon and examine it up-close, potentially revealing further clues about the processes that cause it to shed flecks of dust into space.

NASA will be visiting a similarly enigmatic target in 2026, the asteroid Psyche. This unusual object seems to be a metal-rich body, and may be the relic core of a smashed planetesimal. The mission is due to launch in 2022 and will venture out to the main asteroid belt where Psyche orbits.

Earthly analysis

In December 2020, the sample return capsule from Japan's Hayabusa-2 mission was jettisoned into Earth's atmosphere by its parent spacecraft. After a dazzling descent across the starry Australian night sky, the capsule landed safely and was recovered by a specialist team located near the remote town of Woomera. Within the capsule were containers holding black surface material – small rocks and dust – collected from the asteroid Ryugu. These samples will now be studied by planetary scientists worldwide, including UK-based researchers. After dropping off the capsule, the main Hayabusa-2 spacecraft moved away from Earth and is now preparing for the next phase of its mission, a visit to asteroid 2001 CC21.

Peering into the past

While several other organisations will be exploring Mars's surface with robotic missions in the coming years, JAXA has its eyes on the Red Planet's moons for its spacecraft; the agency is developing the Martian Moons eXploration mission (MMX), which will examine Phobos and Deimos; the craft will also attempt to grab material from the surface of Phobos, which should tell scientists about its history.

Further out, NASA will be launching its 'Lucy' mission to the hitherto-unexplored Trojan asteroids this year; these objects orbit the Sun in positions either side of Jupiter and piecing together their past may reveal clues about the Solar System's construction.

away, right before the researchers' eyes, revealed insights into the asteroid.

Prior to the spacecraft making its daring sampling attempt, the mission serendipitously discovered that Bennu is ejecting thousands of small pieces of rock out into space. Researchers working with the OSIRIS-REx data argued that these particles had a thin, flake-like shape; sure enough, the pictures of material escaping from the TAGSAM collector revealed objects with just such a form. "They look like cornflakes," says Lauretta. "We've got resolved imaging data of the kinds of things we think are in orbit around the asteroid, so it actually turns into a science experiment."

The images showing the TAGSAM collector plunging into Bennu, and the effects on the surface of the spacecraft's thrusters lighting up to reverse the probe's descent, also show fascinating physics. Lauretta says the pictures suggest there's extremely low cohesion between the rocks and small grains that make up the asteroid's surface. "Everything just moved away like a fluid. It's like hitting a puddle of water," he says. "We just kept going. When we hit the surface of the asteroid it barely registered a force."

OSIRIS-REx's experience demonstrates elegantly why some planetary scientists refer to asteroids like Bennu as 'rubble piles'. "It was actually 16.6 seconds after initial contact that the TAGSAM head rose above the point where the original surface was," explains Lauretta. "I don't think there was surface there at that point because we had cratered it, but still. If we hadn't fired those thrusters I don't know how deep we would've sunk."

What lies beneath Bennu's loosely bound surface of rocks, boulders and dust is, at the moment, anyone's guess. "That's one of the next frontiers of asteroids…" says Lauretta. "Probing the interior structure of these rubble piles." Nonetheless, the sample returned by OSIRIS-REx will carry with it an immense amount of information. ▸

◄ OSIRIS-REx's sample will hopefully shed light on Bennu's mysteries, perhaps including why tiny pieces of rock, shown here in 2019, are swirling around it

▼ On return to Earth in 2023, OSIRIS-REx will jettison its sample container for collection in the Utah desert

ILLUSTRATION

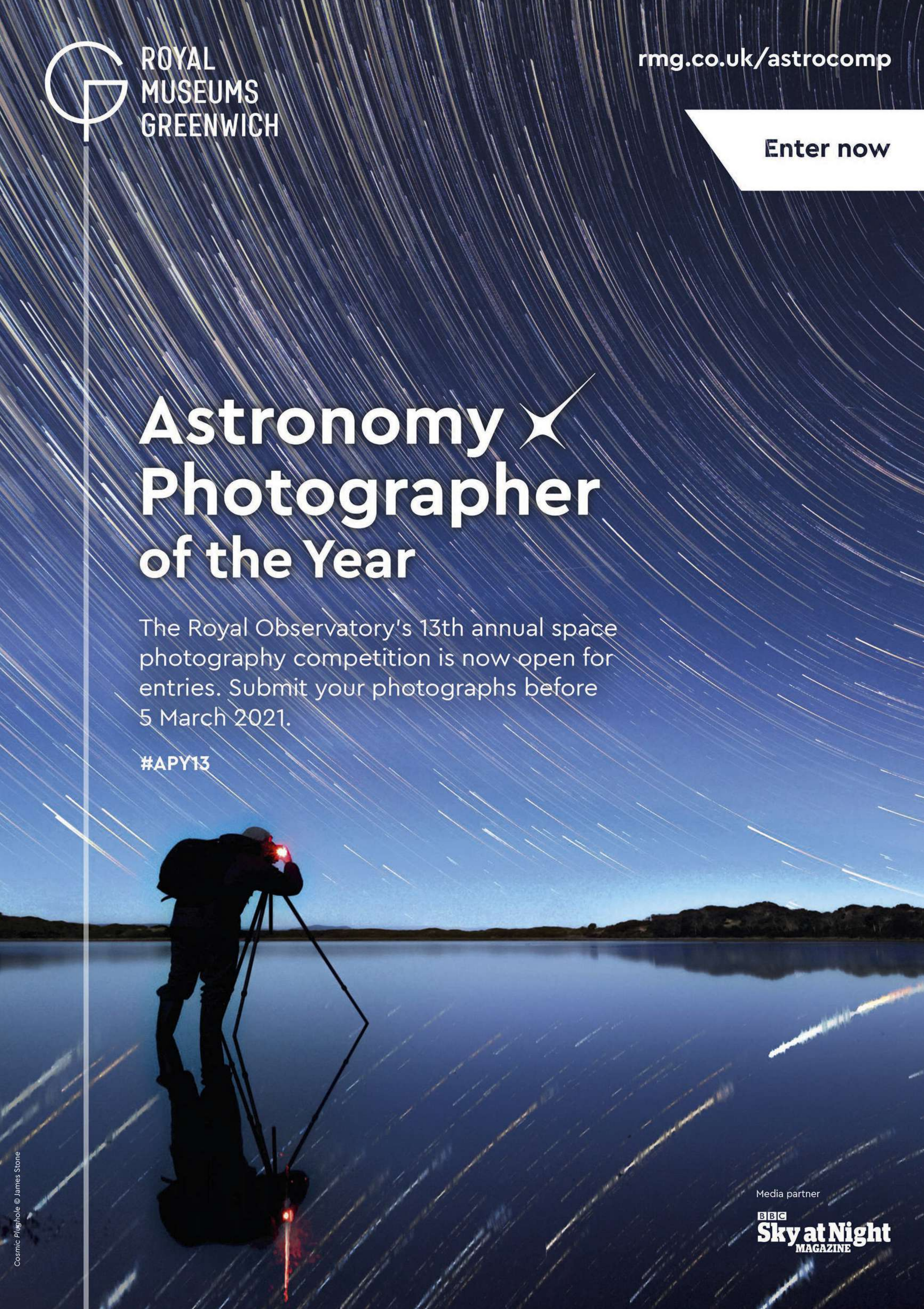
► Having actual asteroid material to scrutinise in the laboratory offers a great advantage over remote observations made with telescopes, says Dr Luke Daly, a meteorite expert at the University of Glasgow who will be helping to analyse the asteroid sample returned by another spacecraft, Japan's Hayabusa-2 mission. "On Earth we can shine light on or through specific areas of it, shoot it with lasers, dissolve it, cut it up and tear it apart at an atomic level – basically really get into the guts of what exactly this stuff is made of," he says.

Such analyses have the potential to offer profound insights into the history of our planet. "These asteroids are rich in water and are currently the most likely candidates for delivering water and organic material to the early Earth," says Daly. "By measuring the composition of the water in these samples we will hopefully get a conclusive answer as to where Earth's oceans came from."

Before anyone can study OSIRIS-REx's sample, Lauretta and his team will have to get it safely home. To do that, on 10 May they'll command the spacecraft to fire its main engines, nudging OSIRIS-REx onto a course towards Earth and a touchdown for the sample-return capsule in the Utah desert. "I'm always amazed and impressed with my flight dynamics team," says Lauretta. "One burn in 2021 sets us up on a two-and-a-half year trajectory that hits Earth in September 2023." For the scientists who'll be getting to glimpse actual fragments of Bennu with their own eyes, that's a date that can't come soon enough.

Will Gater is an astronomy journalist and science presenter. His latest book, *The Mysteries of the Universe*, has recently been published by DK

NASA/GODDARD/UNIVERSITY OF ARIZONA/LOCKHEED MARTIN, KB DS/ISTOCK/GETTY IMAGES, NASA'S GODDARD SPACE FLIGHT CENTER CONCEPTUAL IMAGE LAB


ROYAL MUSEUMS GREENWICH
rmg.co.uk/astrocomp
Enter now
Astronomy Photographer of the Year
The Royal Observatory's 13th annual space photography competition is now open for entries. Submit your photographs before 5 March 2021.
#APY13
Cosmic Plughole © James Stone
Media partner
BBC Sky at Night MAGAZINE

BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

MARCH 2021


PETE LAWRENCE

VIEW MARS NEAR THE PLEIADES

Catch the Red Planet's close encounter with the beautiful star cluster

VESTA REACHES OPPOSITION

Get the best and brightest view of the minor planet

THINK THIN MOON

Locate a wonderful, waxing ultra-thin lunar crescent

About the writers


Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four


Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

✦ The Beehive Cluster, M44, at its highest position
✦ A grouping of Mars, Aldebaran and the Moon
✦ The 'lunar X and Y' clair-obscur effects

Red light friendly


To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

MARCH HIGHLIGHTS

Your guide to the night sky this month

Monday 1

Mars is slowly making its way across the sky south of the Pleiades open cluster in Taurus. Closest approach will occur on the evenings of 3 and 4 March.

Wednesday 3 ▶

Tonight and tomorrow night, mag. +1.0 Mars will be closest to the Pleiades open cluster, separated from the centre of the cluster by 2.7°.

◀ Saturday 6

Mercury reaches greatest western elongation today, appearing separated from the Sun by 27.3°. It isn't that well placed though, shining at mag. +0.2 and rising 40 minutes before the Sun above a flat east-southeast horizon.

Monday 8

As the Moon is slipping into the morning sky, this is a great time to try our 'Deep-Sky Tour' on page 56. This month we're looking at objects around the M96 Group of galaxies in the constellation of Leo, the Lion.

Tuesday 9

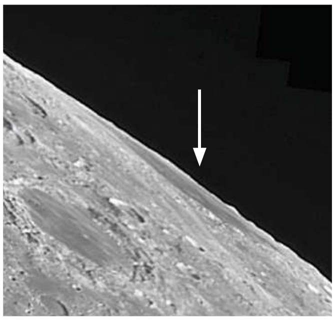
If you have a flat east-southeast to southeast horizon, Mercury, Jupiter and Saturn are joined by a 17%-lit waning crescent Moon from 40 minutes before sunrise.

Wednesday 10 ▶

Mars is now looking small through a telescope at just 6 arcseconds across, but as the planet's tilt gets more side-on to Earth, it should be just about possible to see both the southern and northern polar regions.

◀ Sunday 14

This evening, look low above the western horizon where you should be able to spot a very thin waxing lunar crescent. The Moon sets approximately 1 hour after the Sun.



◀ Monday 15

The Moon's libration (its small rocking and rolling motion) and phase puts features close to the northeast limb in view. Here you'll find Mare Humboldtianum, and craters Nansen, Hayn and Boss.

Family stargazing

Mars passes south of the Pleiades open cluster at the start of March, which is a great opportunity to show young observers these two objects close together. The meeting is also conveniently visible in the early evening. Extending the line of Orion's Belt up and right guides you to the orange star Aldebaran in Taurus. Look out for the sideways V-shaped cluster next to Aldebaran. This is the Hyades cluster and represents the Bull's face. Keep the Belt line going to arrive close to Mars during March's first week. The Pleiades appears above Mars from 1-5 March. **www.bbc.co.uk/cbeebies/shows/stargazing**

Saturday 20 ▶

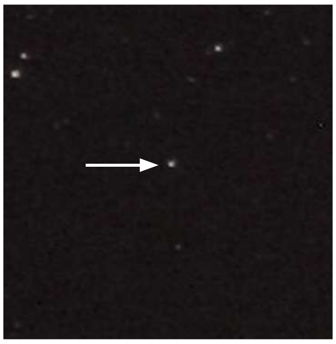
At 09:37 UT the centre of the Sun's disc will cross the celestial equator, an instant in time known as the Northern Hemisphere's spring or vernal equinox.

The 'lunar X and V' clair-obscur effects are visible at 23:15 UT this evening.

PETE LAWRENCE X 11

Thursday ▶

4 Asteroid 4 Vesta reaches opposition today, shining at mag. +5.9 in the constellation of Leo. From a dark-sky location, it might be possible to spot the minor planet using just your eyes. See pages 47, 53, 55 and 60 for more about Vesta.



Friday

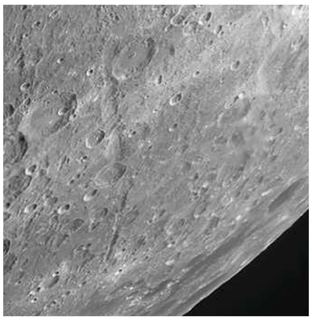
5 If you have access to a very flat east-southeast horizon, take a look low above it from 40 minutes before sunrise to see whether you can spot mag. +0.2 Mercury just 19 arcminutes from mag. –1.8 Jupiter.

◀ Sunday

7 For those with a flat southeast horizon, this morning's 37%-lit waning crescent Moon is 1.5° south southeast of M8, the Lagoon Nebula. Can you image any part of M8 and the Moon in the same photo? Moonrise is at 03:50 UT from the UK's centre.

Friday ▶

12 With the Moon out of the way, find dark skies and locate the wonderful Beehive Cluster, M44, at 21:30 UT, when it's due south and highest in the sky. The view is best suited to binoculars.



◀ Tuesday

16 This and the following two evenings are ideal times to look out for our March 'Moonwatch' target, the crater-chain valley Vallis Rheita. See page 52.

Friday

19 A grouping of mag. +1.2 Mars, +0.8 Aldebaran (Alpha (α) Tauri) and a 33%-lit waxing crescent Moon occurs this evening. The centre of the Moon is 2.3° south of Mars and 4.7° north of Aldebaran at 20:15 UT. Mars and Aldebaran will show similar colours.

Friday

26 Venus succumbs to the Sun today as it reaches superior conjunction, lining up with the Sun on the far side of its orbit from Earth. After today, the planet will slowly return to the evening sky.

◀ Sunday

28 The full Moon occurs close to lunar perigee, meaning it will appear slightly brighter and fractionally larger than an average full Moon.

The clocks go forward by an hour at 01:00 UT, marking the start of British Summer Time.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

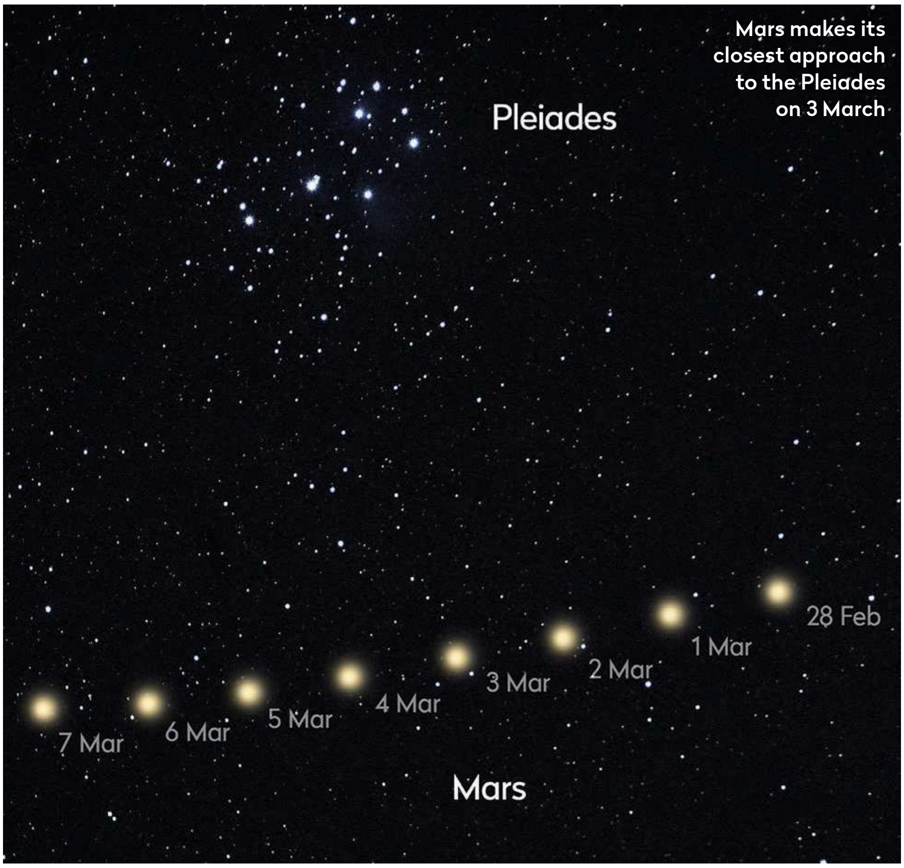
Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

DON'T MISS

MARS AND THE PLEIADES

BEST TIME TO SEE:
1-5 March, with closest approach on 3 March and Moon nearby on 19 March



Mars has been a beacon in our night skies for many months, but due to the increasing distance between it and Earth, it now appears much dimmer than it did at the end of 2020. In addition, through the eyepiece of a telescope, Mars now appears quite tiny, making its surface markings harder to see.

At the start of March, Mars is located 3° south of the beautiful open cluster M45, also known as the Pleiades or Seven Sisters. As it tracks east, Mars also moves slightly north against the background stars. This apparent motion means the planet appears closest to the cluster on the evening of 3 March, the separation distance being around 2.5° on this date.

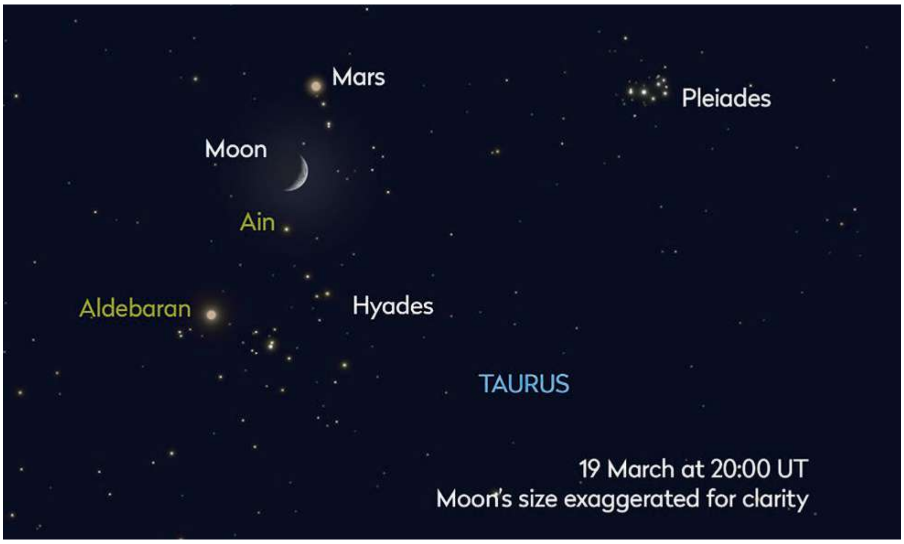
Mars will appear at mag. +1.0 on 3 March, and although a lot dimmer than the mag. –2.6 it achieved last October, its proximity to the Pleiades will no doubt cause considerable interest in the early part of the month.

Binoculars are perfect for watching this conjunction; Mars and the Pleiades will easily fit in the same field of view for typical amateur mid-power binoculars. In addition, the large size of the Pleiades suits such an instrument. Where a scope tends to look through the Pleiades, binoculars reveal many of the fainter stars associated with the cluster while managing to contain it all in a single view.

The conjunction will also be attractive for astro imaging: both objects are bright enough to register on many devices ranging from some smartphones to DSLRs and MILCs. A lens of 200mm focal length combined with a non full-frame DSLR (eg APS-C) will record both objects well.

As we head into the second week of March, Mars will have moved east far enough to sit between the Pleiades and the V-shaped Hyades. The Hyades is an old cluster, the closest to Earth at a distance of 150 lightyears. Estimates put the age of the Hyades at 625 million years, and this explains why its stars appear less vibrant than the 100 million-year-old Pleiades. The distance to the Pleiades is around 444 lightyears, making it appear far more compact than the spread out Hyades.

A 50mm lens on a non-full frame DSLR will capture both clusters and Mars in the same frame. For an added bonus, on 19 March a 32%-lit waxing crescent Moon will sit 2.3° to the south of Mars, between the planet and the northmost star in the main Hyades pattern, Ain (Epsilon (ε) Tauri).



▲ On 19 March, a waxing crescent Moon sits 2.3° south of Mars, above the Hyades

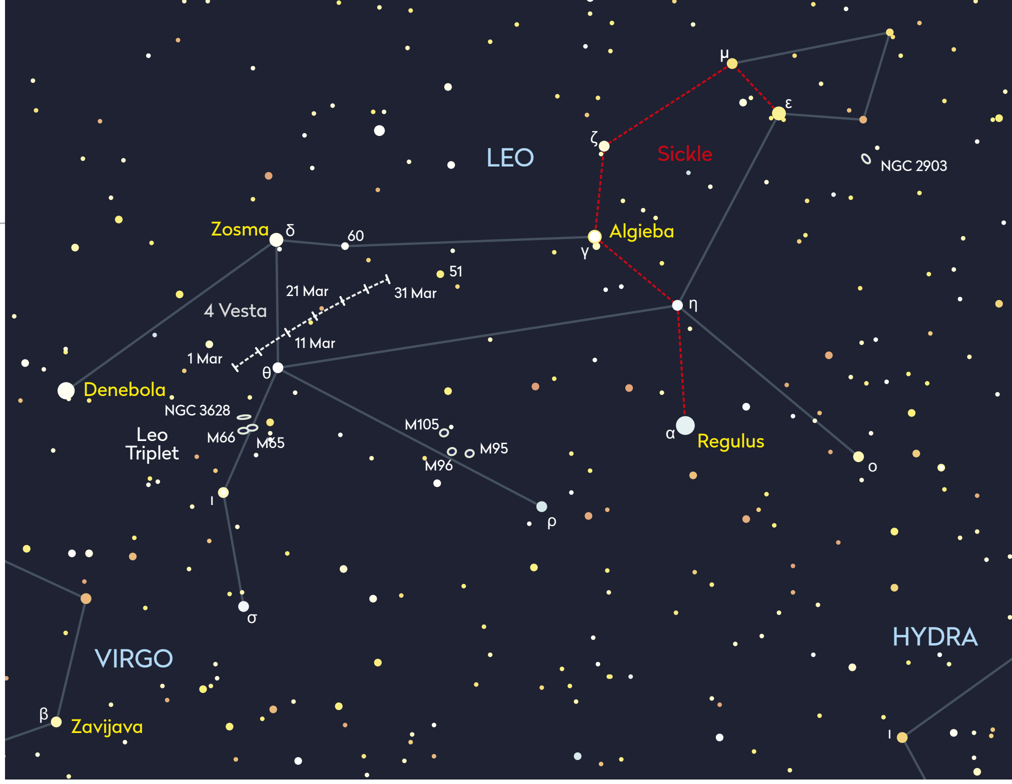
Vesta at opposition

BEST TIME TO SEE: All month, brightest at opposition on 4 March

Minor planet Vesta reaches opposition on 4 March when it will appear like a mag. +5.9 star in the constellation of Leo, the Lion. Despite its stellar appearance, Vesta is a Solar System body and this can be revealed by recording the field of view in which Vesta sits over as many nights as possible during the month.

You'll find that binoculars or a telescope using a low power eyepiece will be the best tools for this. If you manage to record Vesta in the field of view, its presence will become obvious when you compare observations; it will be the object that moves against the background star field.

A number of fainter asteroids are located near to Vesta's position within Leo. Taking a number of wide-field shots of the constellation will reveal their dim dots moving against the background stars.



▲ **Vesta begins March east of the star Chertan (Theta θ Leonis) and tracks northwest, reaching its brightest at opposition on 4 March in the constellation of Leo, the Lion**

At mag. +5.9 Vesta is on the threshold of naked-eye visibility and this month's 'Sky Guide Challenge' on page 56 is to try and spot it unaided. During optimum oppositions Vesta can reach mag. +5.1 and this year's brightness isn't too far off.

Vesta starts the month to the east of mag. +3.3 Chertan (Theta (θ) Leonis) and tracks slowly to the northwest, passing into the main body of the Lion as defined by Chertan, Zosma (Delta (δ) Leonis), Algieba (Gamma (γ) Leonis) and Regulus (Alpha (α) Leonis). Leo is well-placed in March and dark-sky conditions will allow us to view Vesta and the galaxies which lie within the constellation's border.

By the month's end Vesta lies 1° southeast of mag. +5.5, 51 Leonis. On the 31st, Vesta will have dimmed to mag. +6.4.

▸ **More on Vesta on pages 53, 55 and 60**

Spot a thin evening crescent Moon

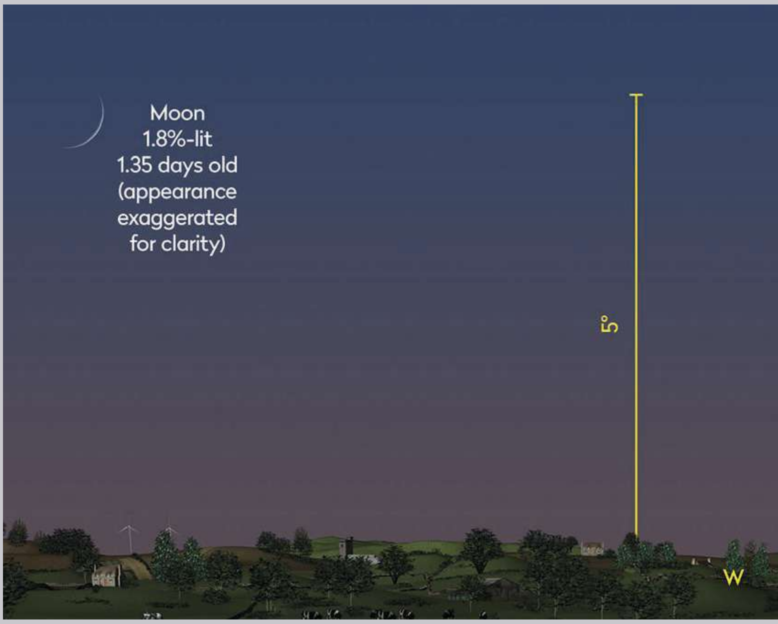
BEST TIME TO SEE: Post sunset on 14 March

On the evening of 14 March there's a chance to catch a thin, 1.8%-lit waxing crescent Moon above the western horizon. This crescent is quite well placed, staying above the horizon for 70 minutes after sunset. To spot it, you'll need a low western horizon and good clear skies.

As ever with thin crescents, throw out all preconceptions of how you expect the Moon to look because this one will be different – being so thin it'll blend perfectly into the bright twilight background. It's a bit like looking for the first star during evening twilight; it's impossible to see until you see it, then it's difficult to miss.

Binoculars are best for thin Moon-hunting, but ensure the Sun has set before using them. If you miss the ultra-thin Moon on 14 March, the subsequent 5%-lit waxing crescent visible on the evening of 15 March will be easier to see, as will the 10%-lit crescent on 16 March.

As the crescent on the 16th is further from the Sun, it'll be visible under darker sky conditions. This is a perfect for seeing the gentle glow of the lunar nightside illuminated by light reflected from planet Earth; a phenomenon called earthshine.



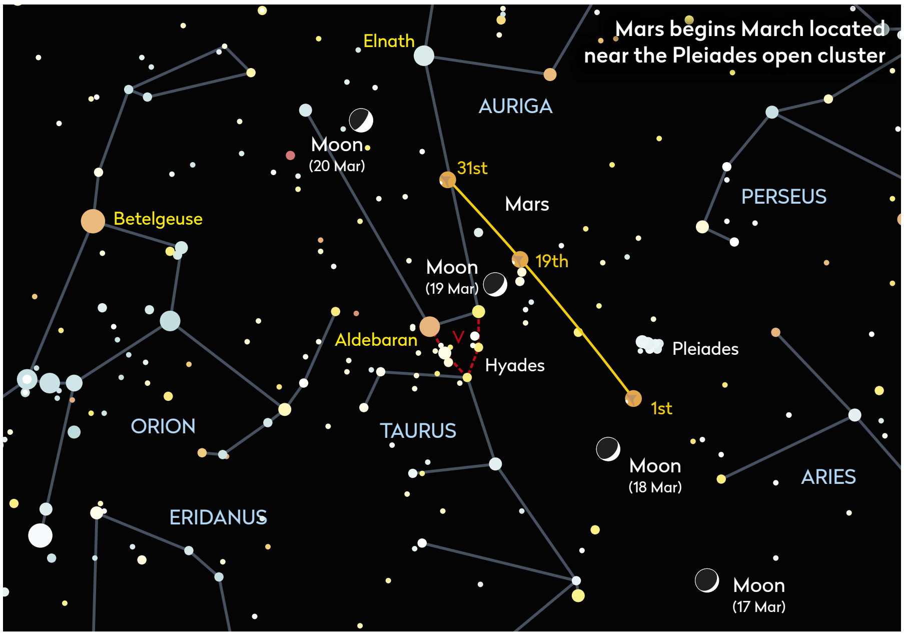
▲ **On 14 March, look above the western horizon around 30 minutes after sunset to catch the 1.8%-lit waxing crescent Moon**

THE PLANETS Our celestial neighbourhood in March

PICK OF THE MONTH

Mars

Best time to see: 1 March, 19:20 UT
Altitude: 50°
Location: Taurus
Direction: Southwest
Features: Albedo markings, polar ice caps, weather
Recommended equipment: 150mm or larger



As far as the UK is concerned, the planets are rather poor at present, all but Mars being hampered by their proximity to the Sun in the sky. However, despite currently being the most northerly planet, the appearance of Mars continues to deteriorate, it being unable to reach its highest position in the sky in darkness.

At the start of March, Mars shines at mag. +0.9 and presents a diminishing disc 6.4 arcseconds across through the eyepiece. By the end of the month, the Red Planet will have dimmed further to mag. +1.3 and through the eyepiece of a telescope shrinks to 5.3 arcseconds. It tracks east throughout the month, passing across the northern part of the constellation of Taurus, the Bull.

At the beginning of March, it is located south of the Pleiades open cluster, M45, lying 2.5° from the cluster on the 4th. It sits 7° north of orange giant Aldebaran on the evening of 19 March, the date when Mars has its monthly visit from the Moon. On this occasion, the Moon will be visible between Mars and Aldebaran, roughly one third of the way along the line joining both objects, starting from the planet. The Moon will appear as a 33%-lit waxing crescent on this date.

The small appearance of Mars's disc through the eyepiece is down to an increase in distance between Earth and the Red Planet.

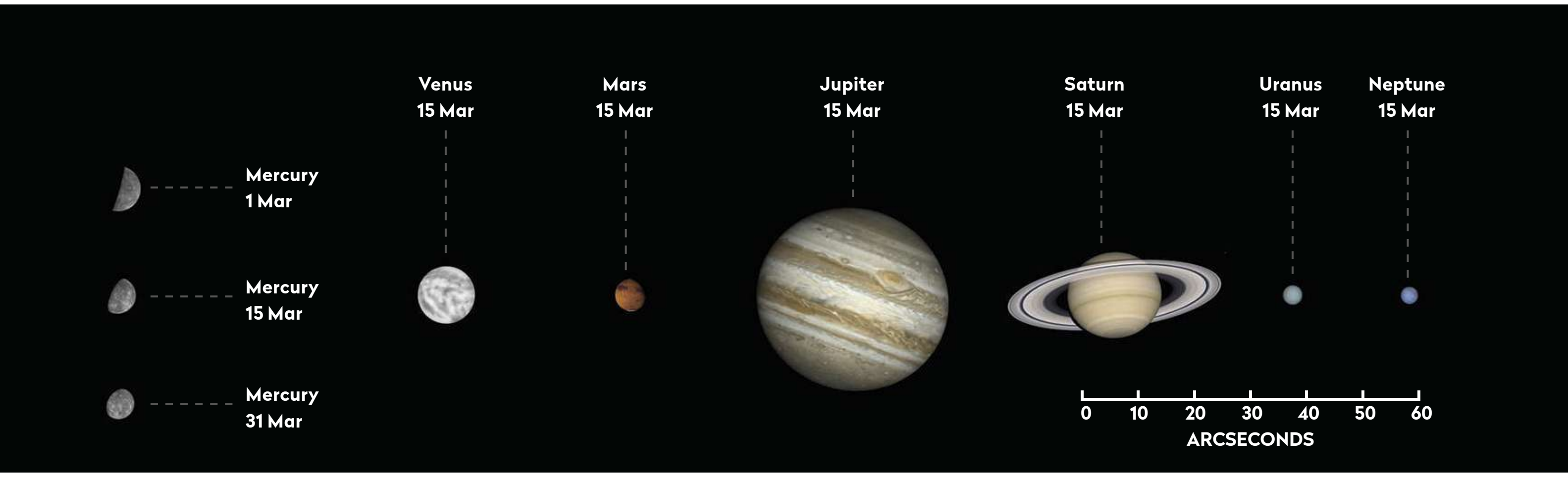
▲ Over March the Red Planet will dim in brightness and present a shrinking disc

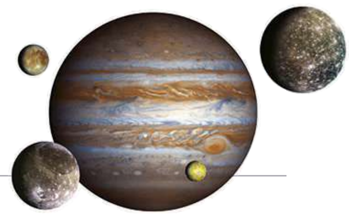
Having enjoyed an excellent opposition last October, Mars is now entering a slow period where it's too small for serious observation. The next opposition occurs on 8 December 2022, when Mars reaches 17 arcseconds across and gets to a good declination for the UK in Taurus. Although smaller in maximum diameter than the 2020 opposition, in 2022, Mars attains an altitude of over 60° when due south.

PETE LAWRENCE X 3

The planets in March

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 6 March, from 30 minutes before sunrise
Altitude: 1˚ (extremely low)
Location: Capricornus
Direction: East-southeast
Mercury is poorly placed in the morning sky all month, despite reaching greatest western elongation on 6 March. Jupiter, Saturn and Mercury appear together this month; on 5 March, mag. +0.2 Mercury lies 19.5 arcminutes from mag. –1.8 Jupiter while mag. +0.9 Saturn lies 8.8˚ to the west. On 10 March, Mercury lies 4.3˚ east of Jupiter with a 10%-lit waning crescent Moon sitting 11˚ to Mercury's southwest. The Moon rises 30 minutes before the Sun on this date, Mercury appearing 10 minutes before the Moon, but you'll find the bright morning twilight will make this a tricky observation.

Venus

Venus reaches superior conjunction on 26 March when it transitions from being a morning to an evening planet. Despite this and a favourable steep ecliptic angle in the west after sunset, Venus is unlikely to be seen throughout March.

Jupiter

Best time to see: 31 March, 40 minutes before sunrise
Altitude: 4˚ (very low)
Location: Capricornus
Direction: East-southeast
Jupiter rises approximately 45 minutes before the Sun at the start of March, but a shallow ecliptic angle with the eastern sunrise sky at this time of year keeps its location is poor.

During March in the morning sky at sunrise, Jupiter just doesn't achieve sufficient altitude to be easily observable. It has a very close encounter with mag. +0.2 Mercury on the 5th, both planets separated by just 19 arcminutes as they pop up above the east-southeast horizon. A 10%-lit waning crescent Moon joins the scene on 10 March, but is more poorly placed than Jupiter! On 31 March, despite rising 70 minutes before the Sun, Jupiter doesn't quite make 9˚ above the horizon before sunrise.

Saturn

Best time to see: 31 March, 50 minutes before sunrise
Altitude: 3˚ (very low)
Location: Capricornus
Direction: Southeast
During March, Saturn can be seen crawling further from the Sun in the morning sky, but despite this the planet remains low. It appears 8˚ to the west of Jupiter on the 1st, a separation that increases to 12˚ by the month's end. A 17%-lit waning crescent Moon sits to the west-southwest of Saturn on the morning of the 9th. At the month's end Saturn attains an altitude of 8˚ above the southeast horizon before the onset of morning twilight.

Uranus

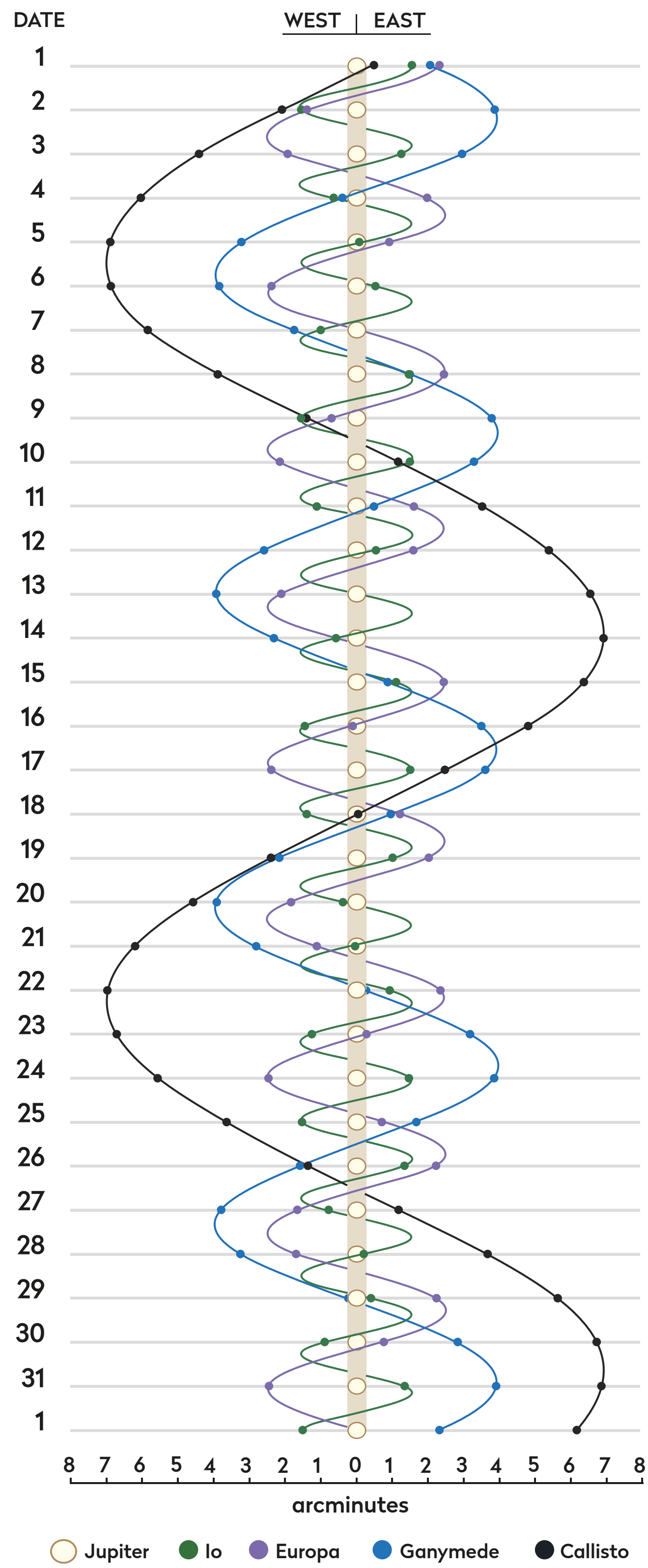
Best time to see: 1 March, 19:40 UT
Altitude: 30˚
Location: Aries
Direction: West-southwest
The observing window for Uranus closes during March as the evening twilight expands to engulf this distant world. Located in southern Aries, Uranus appears 30˚ up as true darkness falls at March's start. By the month's end it has an altitude of less than 5˚ by the time true darkness arrives.

Neptune

Not visible this month – solar conjunction on 10 March.

JUPITER'S MOONS: MARCH

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – MARCH

Explore the celestial sphere with our Northern Hemisphere all-sky chart

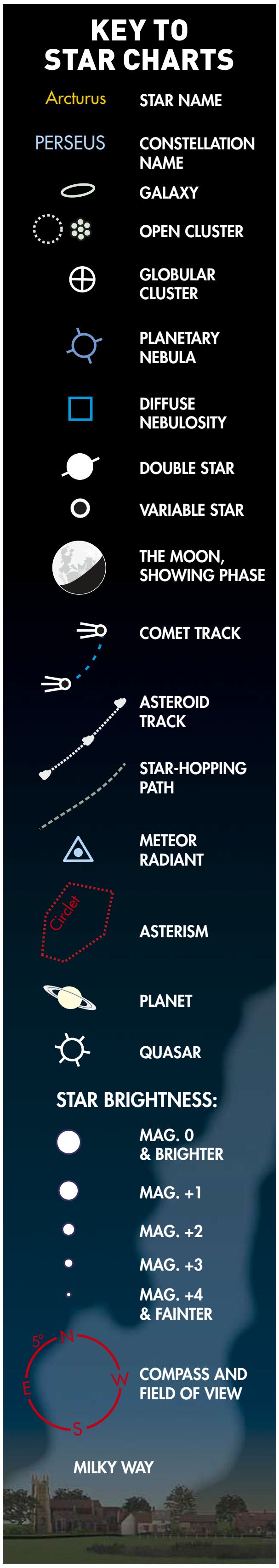


CHART: PETE LAWRENCE

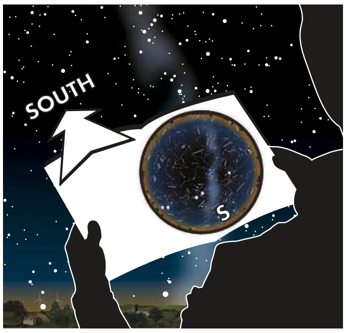
When to use this chart

1 March at 00:00 UT
15 March at 23:00 UT
31 March at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.



Sunrise/sunset in March*

Date	Sunrise	Sunset
1 Mar 2021	06:57 UT	17:48 UT
11 Mar 2021	06:34 UT	18:07 UT
21 Mar 2021	06:10 UT	18:26 UT
31 Mar 2021	06:46 BST	19:44 BST

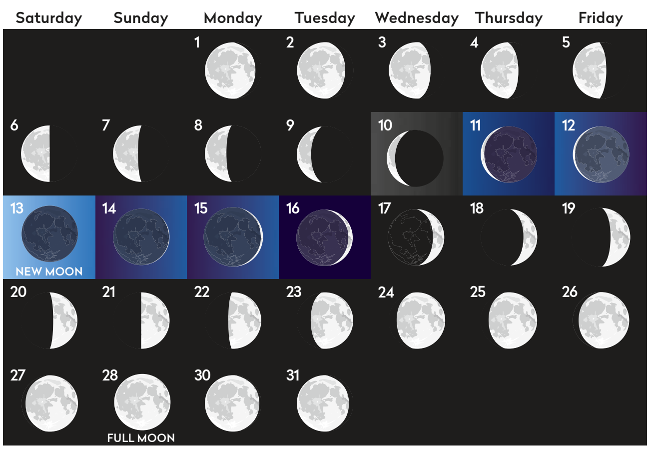
Moonrise in March*

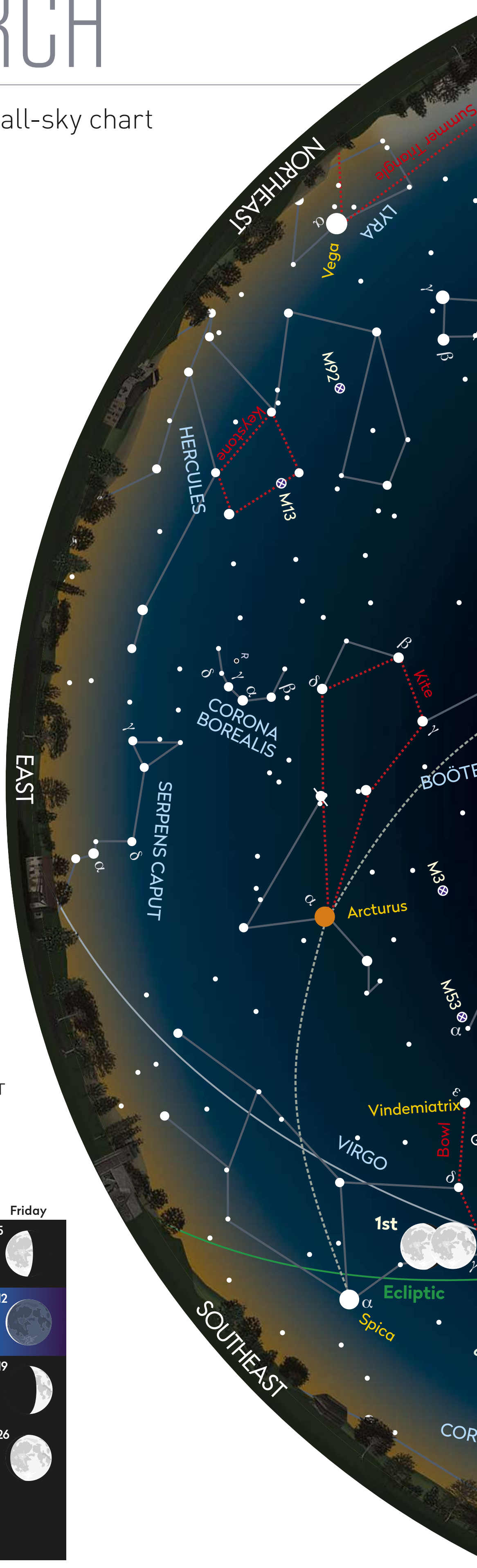
Moonrise times

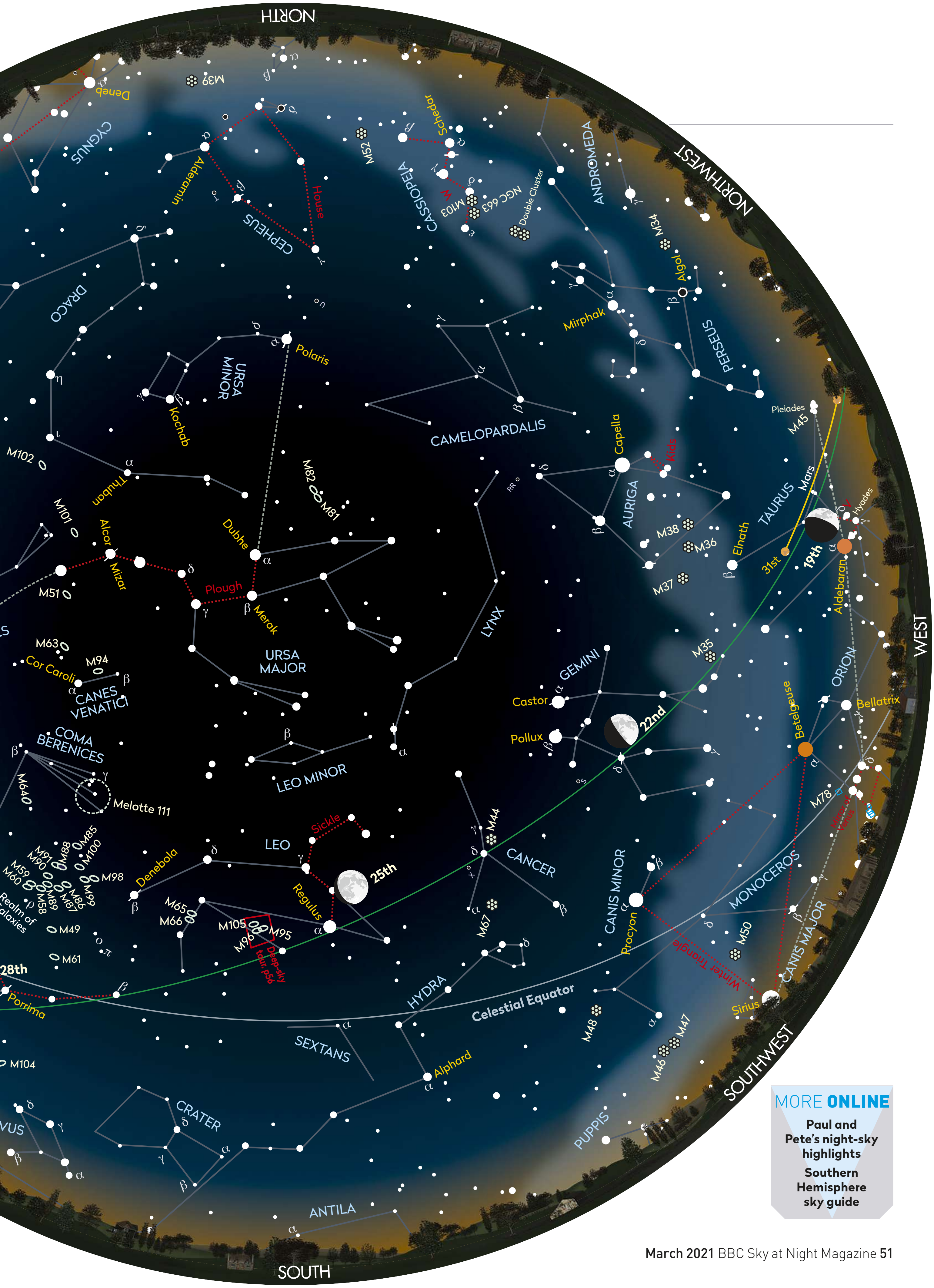
1 Mar 2021, 20:47 UT	17 Mar 2021, 07:57 UT
5 Mar 2021, 01:10 UT	21 Mar 2021, 09:35 UT
9 Mar 2021, 05:36 UT	25 Mar 2021, 13:55 UT
13 Mar 2021, 07:06 UT	29 Mar 2021, 20:47 BST

*Times correct for the centre of the UK

Lunar phases in March







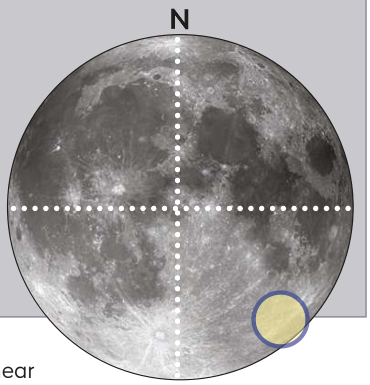
MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

Vallis Rheita

Type: Crater-chain valley
Size: 450km x 30km
Longitude/Latitude: 51.7˚ E, 42.5˚ S
Age: Older than 3.9 billion years
Best time to see: Four days after new Moon (16–18 Mar) and three days after full Moon (30–31 Mar)
Minimum equipment: 50mm refractor



Vallis Rheita is a curious feature visible near the Moon's southeast limb. It appears as a two-part linear trough. The northern part is approximately 30km wide and runs for 300km north from the northern rim section of 46km diameter **Young D**, cutting through the western side of the battered 73km diameter crater **Young**. Ridges appear to cross the valley along its northern route, but these are rim sections of smaller craters. This suggests the valley is formed by overlapping craters, a crater-chain rather than a true geological valley. Four to five distinct flat-floored craters appear in the section between Young D and the western rim of 70km **Rheita**, 230km to the north-northwest of Young D.

Rheita is a well-defined crater. It has a 15km-wide internal rim, battered and contorted by small impacts. Rather than destroy the rim perimeter completely, these impacts appear to give the rim some extra texture. As a consequence, the interface between the sloping sides of Rheita and its smooth, flat floor remains relatively well defined. A single, central peak sits at the centre of the crater.

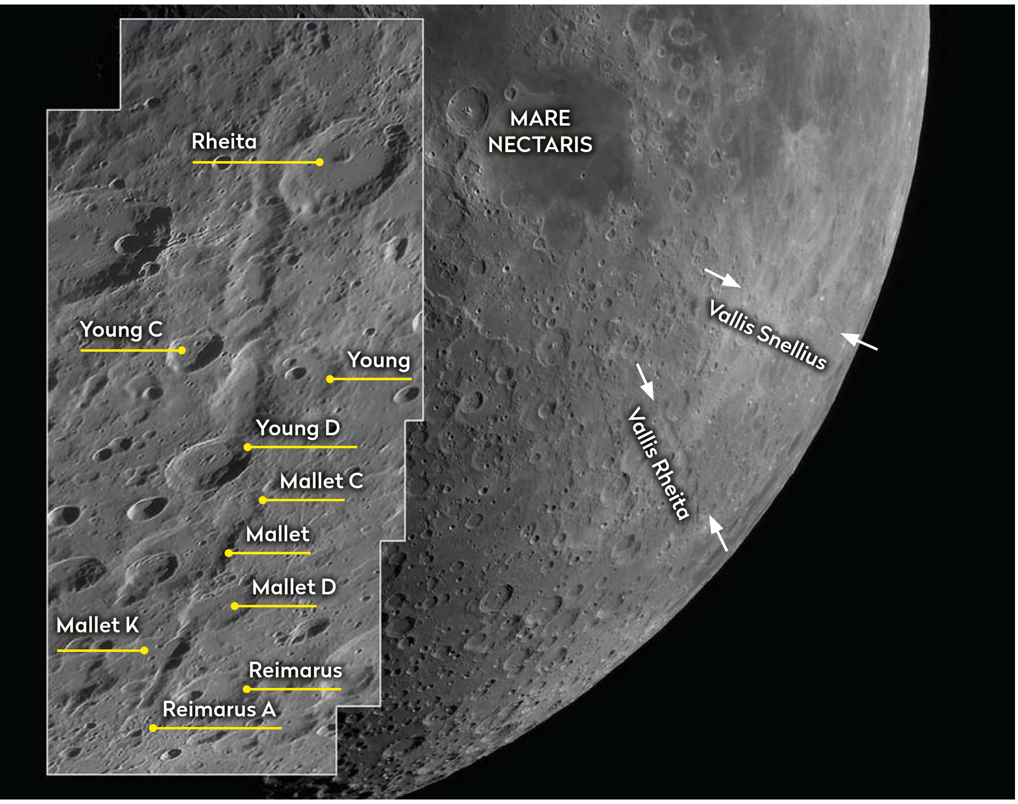
Vallis Rheita continues north-northwest past the western edge of Rheita. Its form diminishes as it does so and it eventually becomes difficult to follow or determine where it actually stops. Returning to the southern end, which terminates at Young D, the valley can be seen to continue further south from 28km **Mallet C**, an irregular shaped crater located immediately southeast of Young D.

The nature of the valley changes as it runs south-southeast of Mallet C. Here it becomes noticeably thinner at just 10km wide, a third the width of its northern section. The form of overlapping craters is less evident here, although not completely absent. This could be due to more extreme foreshortening. The valley appears more regular and with a more continuous flat floor. A number of major interruptions occur, most notably from 42km **Mallet D**, 43km **Mallet K** and 29km **Reimarus A**, the latter located near to the southern end of the valley.

Vallis Rheita is formed by a crater-chain rather than a true geological valley

A clue to Vallis Rheita's formation comes from two nearby features. Running between 177km Petavius and 126km Furnerius to the north is **Vallis Snellius**. This can be tricky to see as it appears heavily eroded. It's the longest named valley on the Moon, running for a total length of 590km. The clue is revealed when the orientation of both valleys is studied: they both appear to converge at 350km **Mare Nectaris**, the Sea of Nectar, located 750km northwest of Rheita. This leads to the conclusion that the most probable formation mechanism for Vallis Rheita and Vallis Snellius is that they are secondary impacts from the formation of Mare Nectaris.

The lengths of both valleys mean that sections of them remain near to the terminator over several nights and, as is the case with many lunar features, this is the best time to observe them. When near to the terminator, the low Sun angle casts impressive and detailed shadows, picking out many of the structures which would otherwise remain hidden with the Sun overhead. As a consequence, make sure you revisit these features often to get the full picture of how their appearance changes over time.



▼ Both Vallis Rheita and Vallis Snellius appear to converge at Mare Nectaris

PETE LAWRENCE X 3

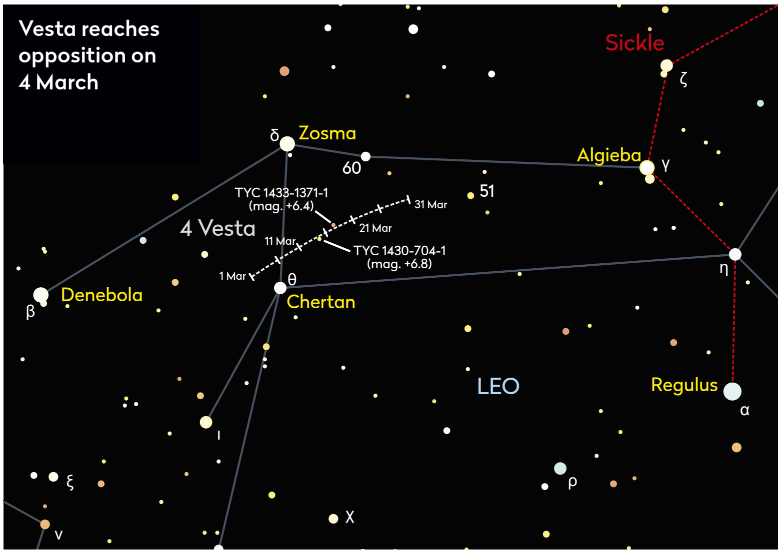
COMETS AND ASTEROIDS

Catch asteroid 4 Vesta as it reaches opposition in the constellation of Leo

4 Vesta holds the accolade of being the brightest of the asteroids. During a favourable opposition this 525km object can reach mag. +5.1, bringing it well into naked-eye territory. This month, Vesta reaches opposition on 4 March, slightly off its most favourable brightness at mag. +5.9, but still theoretically within reach of the unaided eye from a dark-sky site. Our 'Sky Guide Challenge' on page 55 is to try and achieve this rare sighting.

Fortunately, Vesta is located in a region of sky that reaches a decent altitude from the UK as it crosses southern skies around midnight UT. The asteroid is located in the eastern portion of Leo, the Lion, starting the month slightly less than 2° east of mag. +3.3 Chertan (Theta (θ) Leonis). On the 1st, it shines at mag. +6.0 and slowly brightens to mag. +5.9 by the 4th.

As the month slips by, Vesta tracks northwest, further into the body of the Lion. It ends its monthly track 2.5° southwest of mag. +4.4, 60 Leonis and 5° west-southwest of Zosma (Delta (δ) Leonis). This part of the sky is away from the Milky Way and therefore devoid of lots of stars that are a similar brightness to Vesta, which might cause confusion: along its track in March, the two brightest stars it passes are of magnitudes +6.8 and +6.4!



Vesta is a large object and it orbits the Sun once every 3.63 years, with an orbit that takes it out as far as 2.57 AU from the Sun and as close as 2.15 AU. At its dimmest, Vesta can be mag. +8.5. As its distance from us changes over the course of our respective orbits, its angular diameter changes from 0.2 to 0.7 arcseconds.

▸ **Read more about Vesta on pages 47, 55 and 60**

STAR OF THE MONTH

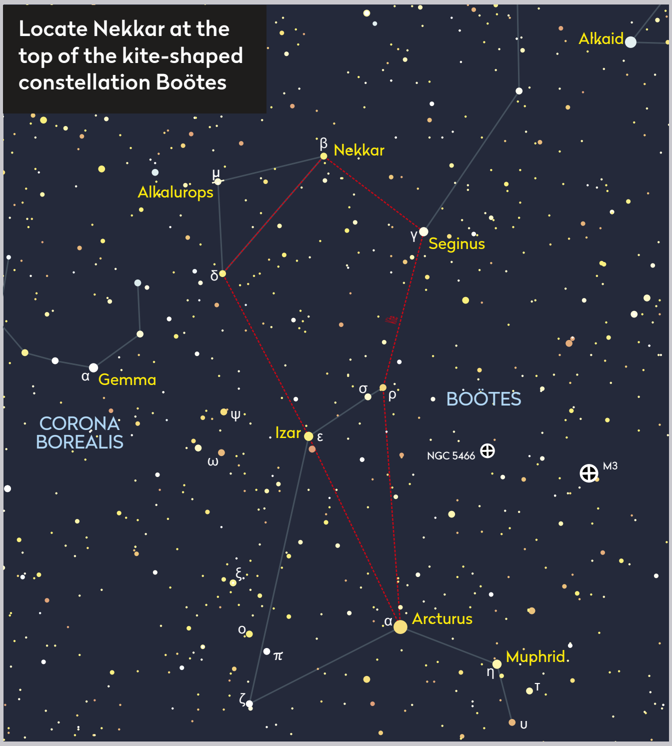
Nekkar, the northern marker of Boötes

Boötes is a large kite-shaped constellation to the southeast of the Plough asterism. The curved handle of the Plough, extended away from the blade, arcs around to Arcturus (Alpha (α) Boötis), the orange-hued star that sits at the kite's base. The kite-shape is about as high as the Plough is long and Nekkar (Beta (β) Boötis) at its northern tip.

Despite its beta status, mag. +3.5 Nekkar is the sixth brightest star in Boötes. It lies at a distance of 225 lightyears and is estimated to be 3.4 times as massive and 170 times as luminous as our Sun. Its spectral classification is G8IIIa, indicating it's a yellowish luminous giant. Nekkar is a slow rotator, with an estimated rotation period of 200 days. (Our Sun has an equatorial rotation period of 27 days.) The rotational axis is inclined by around 30° to our line of sight.

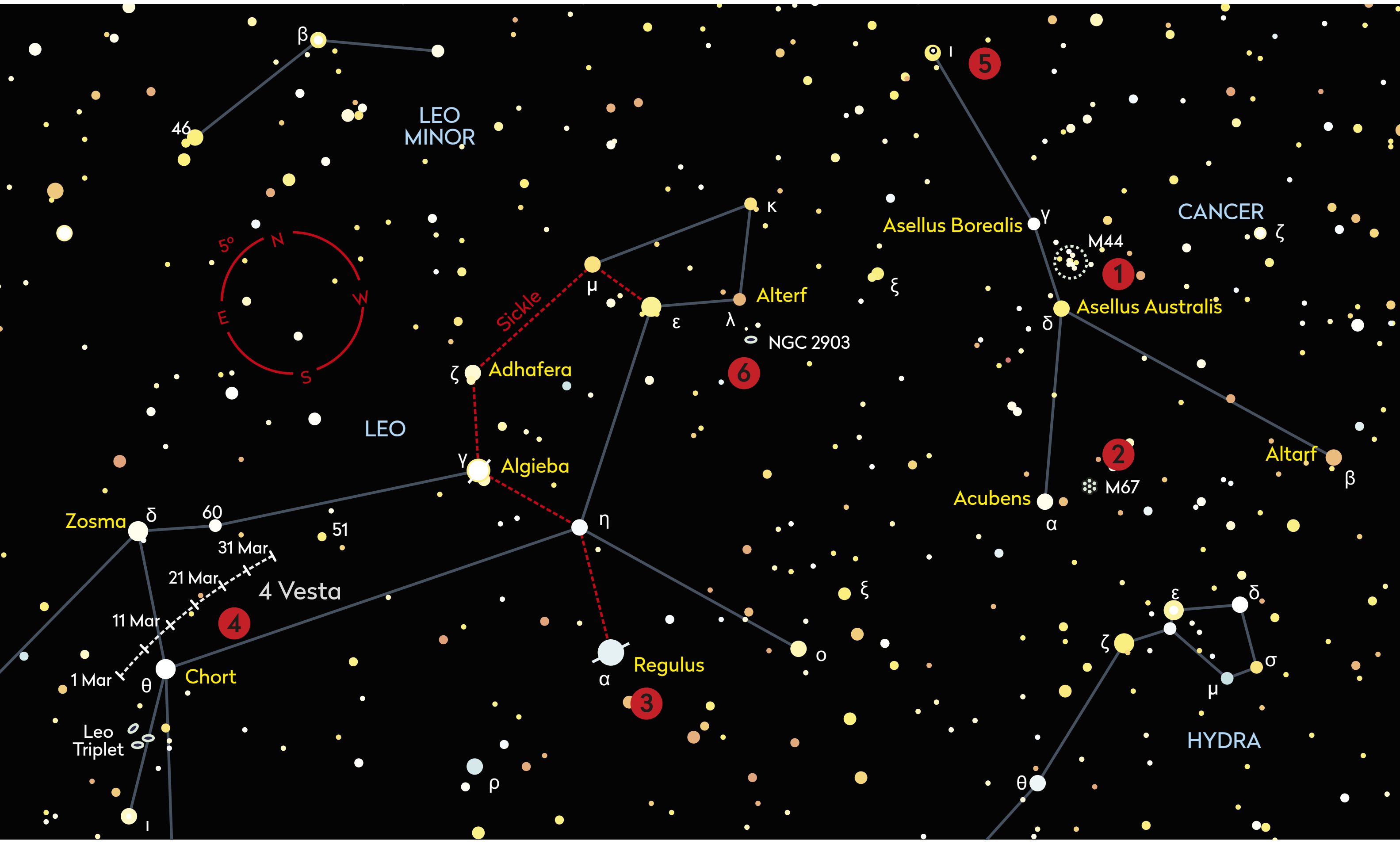
Nekkar is classed as a marginal barium star, one that shows an enrichment of barium in its spectrum. Such enrichment normally comes from a companion such as a white dwarf star, but to date no companion has been found.

Now in a mature phase of its evolution, Nekkar is on the verge of becoming a red giant. As it enters this phase, it will become larger and brighter, perhaps redressing the balance and regaining its true beta brightness.



BINOCULAR TOUR With Steve Tonkin

Our wide-field picks include open cluster M67, which hosts stars that resemble our Sun



1. Praesepe, M44

10x50 Just above Asellus Australis (Delta (δ) Cancri) is what in pre-telescopic times was called 'Nephelion' (the Little Cloud), which describes a naked-eye view. Praesepe is a close and populous cluster, making it ideal for binoculars, which reveal that it appears brighter in the middle. This results from conservation of momentum in interactions between heavy and light stars; the latter must move faster, and hence further from its centre. ☐ **SEEN IT**

2. M67

10x50 Just under 2° west of Acubens (Alpha (α) Cancri), your binoculars unveil a misty patch that brightens towards the centre. M67 is about the same apparent size as the Moon and hosts about a hundred stars of a similar type and age as our Sun. As it is fairly nearby (2,700 lightyears), M67 is one of the most studied open clusters because of the number of proxies for the Sun it contains. ☐ **SEEN IT**

3. Regulus

10x50 Most multiple stars with components of very different magnitudes are difficult to split, so it's pleasant to find an easy one! Regulus (Alpha (α) Leonis) itself shines at mag. +1.4, nearly five hundred times brighter than its companion. Fortunately, they are separated by nearly 3 arcminutes, allowing even small 'compact' binoculars to show the companion star. This is a true multiple star, not a chance line-of-sight pairing. ☐ **SEEN IT**

4. Vesta

10x50 Asteroid 4 Vesta starts March at mag. +6.1, less that two degrees east of Chort (Theta (θ) Leonis). It brightens slightly as it moves towards 51 Leonis, before fading by about half a magnitude at the month's end. It will be brighter than any star near its path, so it should be easy to tell which is the asteroid but, if you are unsure, it moves each night. ☐ **SEEN IT**

5. Iota Cancri

15x70 You should be able to identify Iota (ι) Cancri with your naked eye. This is a double star; the mag. +4.0 primary is a yellow giant, and the secondary is a white main sequence dwarf that shines at mag. +6.0. Only 31 arcseconds separate them, so you'll appreciate the 15x70s when you try to split this true binary star, which has an orbital period of 65,000 years. ☐ **SEEN IT**

6. NGC 2903

15x70 You'll need dark transparent skies for this month's most challenging target. First, identify Alterf (Lambda (λ) Leonis). A degree south of it are a pair of fainter stars about half a degree apart. Our target galaxy is just south of the fainter, more easterly one. Try using averted vision by directing your gaze back on Alterf, but concentrating your attention on the location of the galaxy. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 2

THE SKY GUIDE CHALLENGE

Find a dark-sky location and try and spot asteroid 4 Vesta with the naked eye

4 Vesta has the potential to become brighter than any other asteroid. Like all asteroids, its brightness varies over the course of its orbit. Under favourable conditions it can reach mag. +5.1 ,which puts it within fairly easy naked-eye territory from a dark-sky site. At its dimmest, Vesta can drop down to mag. +8.4, necessitating at least binoculars or a telescope to see. This month, we're challenging you to find and record Vesta with nothing more than your eyes.

Vesta reaches opposition on 4 March when it will shine at mag. +5.9, a fraction dimmer than Uranus at opposition. The naked-eye threshold magnitude is typically stated as mag. +6.0, a value which isn't too hard to achieve as long as you live under good dark skies. Such skies will be required if you intend to look for Vesta close to opposition. Resources such as **darksitefinder.com/map** or **www.lightpollutionmap.info** are great tools for finding dark skies near you.

At opposition, on 4 March, Vesta will shine at mag. +5.9

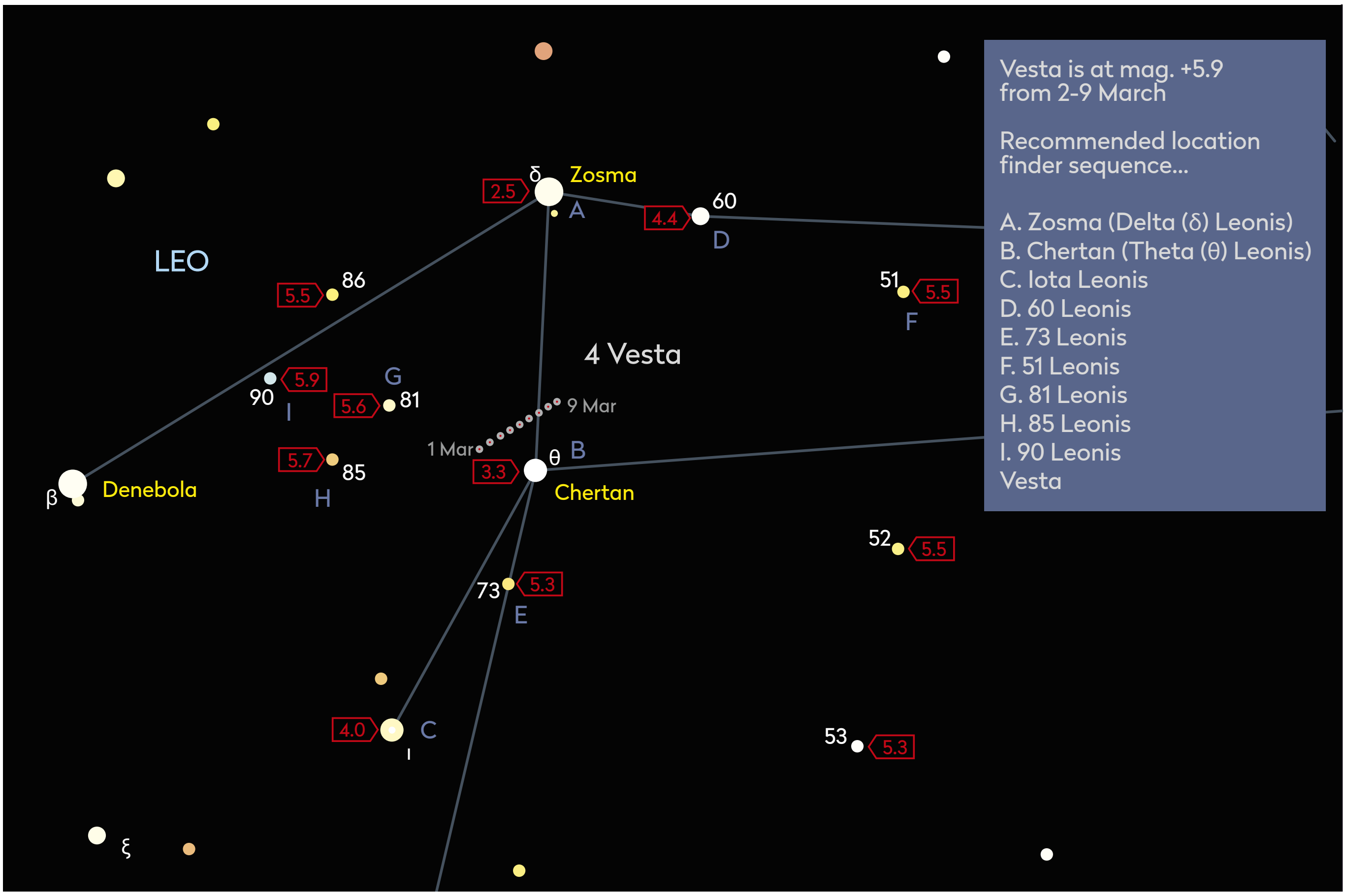
The Moon is in a waning gibbous phase at the start of March when Vesta is brightest, so plan any attempt before moonrise. On the evening of 1 March moonrise is at 20:54 UT, on 2 March it's at 22:22 UT, on 3 March it's at 23:48 UT and on 5 March at 01:14 UT. There is no moonrise on 4 March. As you can see, as opposition date approaches, the Moon moves conveniently out of the way.

The region where Vesta is located reaches highest altitude, due south, at 00:40 UT at the start of March; over 50° above the southern horizon from the UK. This moves the asteroid out of any low horizon murk. Located near the rear of Leo, the Lion, the Milky Way is also absent. This removes a lot of the fainter stars which could otherwise be confused for Vesta.

You will need to utilise all the tricks if you stand a chance of succeeding. Give your eyes at least 20 minutes in total darkness. Use the trick of averted vision – looking slightly away from the faint object you're looking for, to place its dim light on a more sensitive part of your retina. We'd also recommend memorising the finder sequence we've prepared (below) so you don't compromise your dark adaption by looking at the chart, even under a red light.

A chair or recliner will help you observe comfortably, an important and often overlooked aspect when looking for faint objects. Use our finder sequence and tick off the navigational stars one by one. If your eyes and sky are good enough, you may pull off what is, without question, one of the trickier challenges we've set.

▸ **Read about Vesta on pages 47, 53 and 60**



▲ **On Vesta's trail: familiarise yourself with our navigational finder sequence of stars before you allow your eyes to become dark adapted**

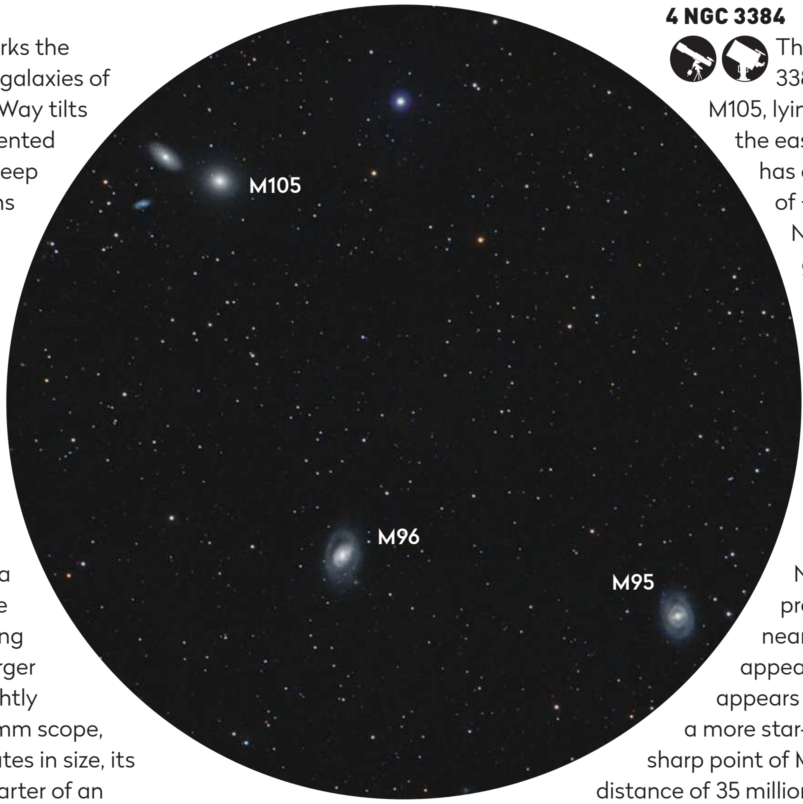
DEEP-SKY TOUR

Our exploration of galaxies in the constellation of Leo, the Lion includes M96 Group members

1 M95

Leo, the Lion marks the transition to the galaxies of spring. As the winter Milky Way tilts out of the way, we are presented with a sky that looks into deep galactic space. Leo contains many galaxies and two famous triples; M65, M66 and NGC 3628 near the Lion's back leg, and M95, M96 and M105 near its belly, 3.6° northeast of mag. +3.8, Rho (ρ) Leonis.

Located 33 million lightyears from the Sun, M95 is a mag. +9.7 barred spiral appearing surprisingly bright through a small telescope. It looks like a diffuse glow, intensity rising sharply to a bright core. Larger scopes show its glow is slightly elongated. Through a 300mm scope, M95 appears 5x3.5 arcminutes in size, its bright core roughly one-quarter of an arcminute across. Magnifications over 200x reveal a mottled texture across the outer regions. ☐ **SEEN IT**



▲ **Clockwise from bottom right: our first three galaxy stops – M95, M96 and M105 – are examples of a barred spiral, an intermediate spiral and an elliptical**

FRANZ KLAUSER/ MANFRED WASSHUBER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

2 M96

M96 is visible in the same low-power field as M95, 41 arcminutes to its east and a fraction north. It's the lead entry in the M96 Group of galaxies and also the brightest at mag. +9.2. M96 is an intermediate spiral, a class of galaxy that has a core that's somewhere between barred and circular in shape. We see an object with two regions, an outer halo and a compact core. A 250mm scope reveals the core and outer halo are elongated, with the halo appearing 4x2.5 arcminutes in size, surrounding an elliptical core measuring 2x0.5 arcminutes. ☐ **SEEN IT**

3 M105

M105 is classed as an elliptical galaxy, a large ball of stars with no hint of spiral structure. It sits 48.3 arcminutes north-northeast of M96 and shines with an integrated magnitude of +9.3. M105 appears to brighten smoothly to a point nucleus. A 300mm scope reveals a glow 4x3 arcminutes in size. ☐ **SEEN IT**

4 NGC 3384

The ancient elliptical NGC 3384 is easy to find from M105, lying just 8 arcminutes to the east-northeast. NGC 3384 has an integrated magnitude of +10.0. Since M105 and NGC 3384 are easy to get in the same field of view, it is interesting to compare them. NGC 3384 is obviously dimmer and smaller than M105, appearing like a mini version of the brighter galaxy.

A large scope highlights the differences well, NGC 3384 with a more pronounced elongation, nearly four times as long as it appears wide. Its central core appears round and concentrated to a more star-like centre, instead of the sharp point of M105. The galaxy lies at a distance of 35 million lightyears and is an M96 Group member. ☐ **SEEN IT**

5 NGC 3412

Lenticular galaxy NGC 3412 shines with an integrated magnitude of +10.6 and is to be found northeast of the main trio. A lenticular shows a core bulge with a flattened disc but no spiral structure. Find NGC 3412 by centring on M105 then heading north. Move past a pair of mag. +8.4 and +9.4 stars (HIP 52744 and HIP 52746), arriving at a mag. +8.6 star (HIP 52775) 0.8° north of M105. NGC 3412 is 0.8° east of this star.

The surface brightness is reasonably high and the galaxy stands out well through smaller apertures. A 150mm scope shows it to have a star-like nucleus, while larger scopes reveal an elongated shape surrounding a circular core approximately one-third of an arcminute in diameter. ☐ **SEEN IT**

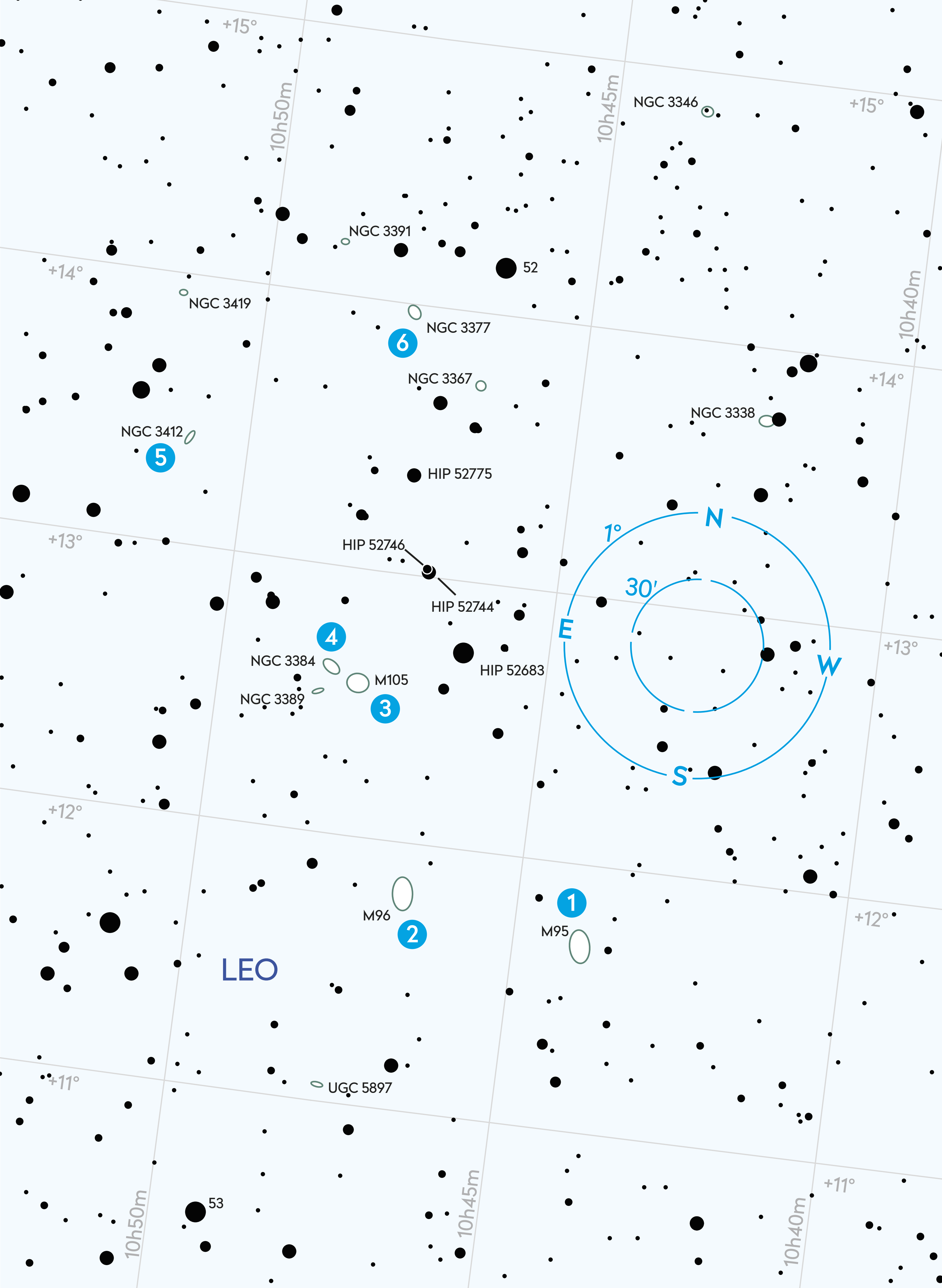
6 NGC 3377

Our final M96 Group target is NGC 3377, an elliptical galaxy located 1.4° north of M105. It shines with an integrated magnitude of +10.2, most of which comes from its compact, circular core region. This object is a nearer member of the group, at an estimated distance of 26 million lightyears.

A 250mm instrument reveals a core surrounded by an elongated outer halo approximately 2x1 arcminutes in size. A 300mm scope virtually doubles the galaxy's size, revealing it as an elongated halo with an impressively bright core. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

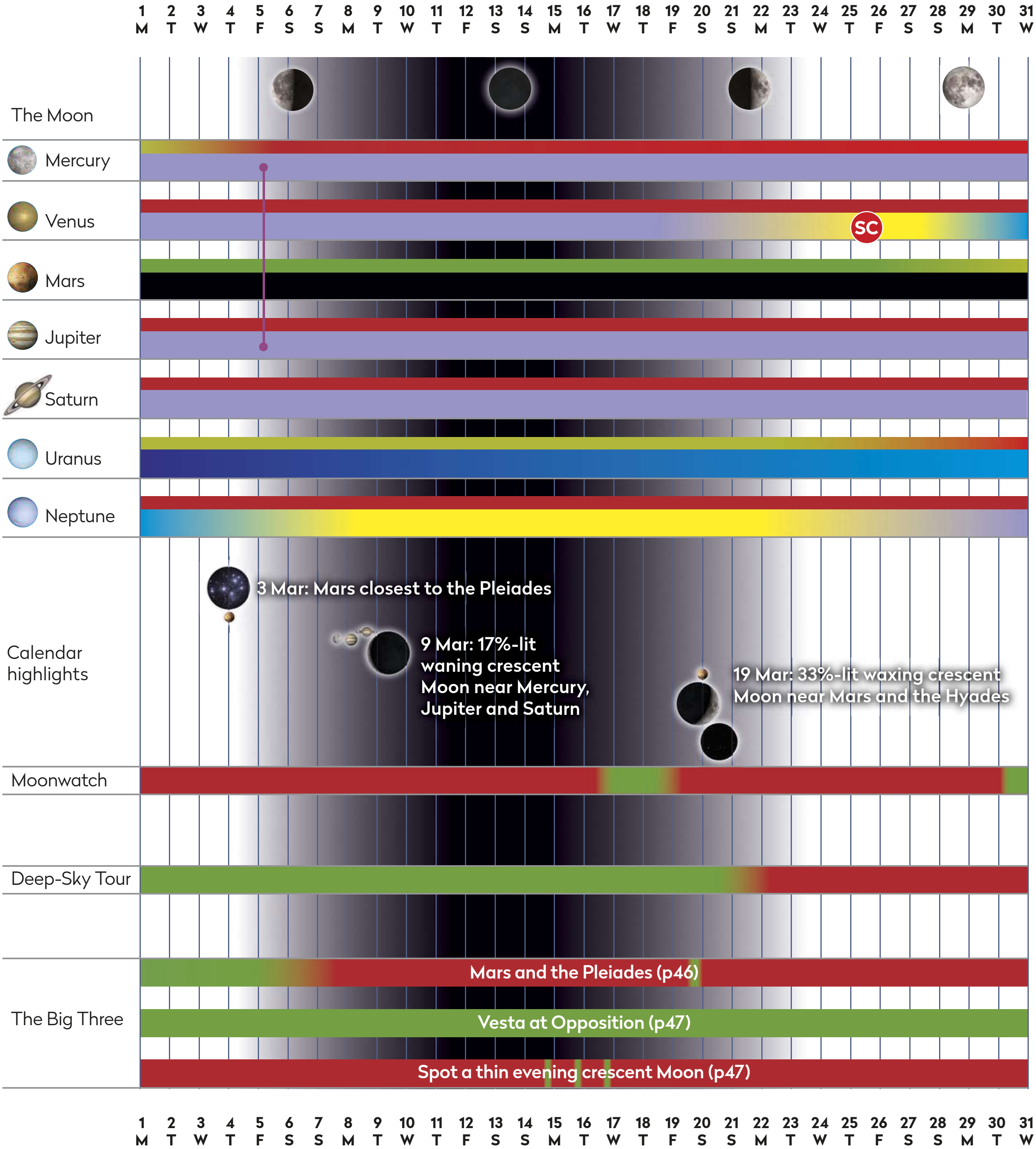
More **ONLINE**
Print out this chart and take an automated Go-To tour. See page 5 for instructions.



+15°
10h50m
10h45m
NGC 3346
+15°
NGC 3391
52
+14°
NGC 3419
NGC 3377
6
10h40m
NGC 3367
+14°
NGC 3338
NGC 3412
5
HIP 52775
+13°
HIP 52746
1°
N
30′
HIP 52744
E
4
NGC 3384
M105
HIP 52683
W
+13°
NGC 3389
3
S
+12°
M96
1
M95
2
+12°
LEO
+11°
UGC 5897
+11°
53
10h50m
10h45m
10h40m

AT A GLANCE

How the Sky Guide events will appear in March



KEY

Observability: Optimal, Poor

Best viewed: Morning twilight, Daytime, Evening twilight, Night

Sky brightness during lunar phases: Dark (first quarter), Light (full Moon), Dark (last quarter), Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

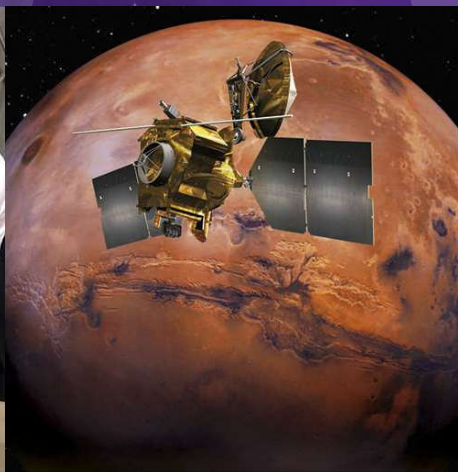
CHART BY PETE LAWRENCE

Listen to Radio Astronomy

the podcast from BBC Sky at Night MAGAZINE

THE PUBLISHER PODCAST AWARDS SHORTLISTED

Explore the wonders of the Universe with *BBC Sky at Night Magazine* in our regular podcasts, released four times a month.
Visit **www.skyatnightmagazine.com/podcast**


Find out all the latest space news and look back over historic space missions with the *BBC Sky at Night Magazine* team. Each month we look at the biggest stories in astronomy and give you our top stargazing tip to see in the night sky.

GARY DOAK / ALAMY STOCK PHOTO

Star Diary **is our brand-new monthly fixture, bringing you advance notice of the best astronomical sights in the month ahead. Whether you're just starting out or have been doing astronomy for years, our expert observing advice will ensure you don't miss out on the best the night sky has to offer.**

Listen to interviews with the leading minds in space science and exploration – be they astronauts, mission controllers or the scientists trying to unravel the mysteries of the cosmos. Previous interviewees include: Chris Lintott, Jim Al-Khalili and Katie Mack.

Listen now!

Visit **www.skyatnightmagazine.com/podcast** for more details, or to listen back through our archive of 70+ episodes, including on-location specials from the BlueDot Festival and Kielder Observatory. Radio Astronomy is also available through most podcast apps.

Rock of wonder:
Vesta is the brightest
object in the asteroid belt

Finding VESTA

Asteroid 4 Vesta may hold clues about the early Solar System, but its discovery is just as intriguing. **Emily Winterburn** uncovers the Celestial Police, an elite group of planet-hunting astronomers

Vesta, the brightest asteroid in our Solar System's asteroid belt, will be at opposition on 4 March 2021. Although Vesta can be seen with the naked eye in locations with no light pollution, it can be a challenge to do so. With a magnitude of +5.9 it might just be possible, but it will be perfectly visible with binoculars or a moderate aperture telescope. You'll be able to find it in the constellation of Leo, the Lion.

Vesta was one of the very first asteroids to be discovered and its story is one full of failure, jealously and discredited theories, as all good science history should be.

Today we know of around two million asteroids in our Solar System's asteroid belt between Mars and Jupiter, but 250 years ago the existence of anything at all in that area of the sky was mere speculation. In 1766 a German astronomer and mathematician, Johann Daniel Titius formulated a mathematical law for explaining and predicting the spacing between planets in a solar system. This is the first discredited theory we will meet in this story. According to Titius's law, astronomers should find a planet between Mars and Jupiter as well as more, further out, yet none at this point had been found. Despite this lack of proof, six years after Titius first published his law it was adopted and popularised by German astronomer Johann Elert Bode. Then, on 13 March 1781, William Herschel discovered Uranus where the law predicted a planet should be.

Founding the 'Celestial Police'

Following this success of what had now become the Titius-Bode law, interest in that region between Mars and Jupiter grew. Baron Franz Xaver von Zach and Johann Hieronymus Schröter, owner of an observatory at Lilienthal in Germany, both took it upon themselves to create and galvanise an active community of astronomers to search for missing planets. After a suggestion made by Joseph-Jérome de Lalande, Zach and Schröter, together with Karl Harding, Heinrich Olbers, Freiherr von Ende and Johann Gildemeister formed a group calling themselves the 'Celestial Police'. Their aim was to organise and coordinate a large, international project to find the missing planet by assigning different sections of the sky to different astronomers across the world. In all, they wrote to 24 astronomers across Europe, inviting them to join the Celestial Police ▸

▲ Johann Daniel Titius devised a law about the spacing of planets

MATTEO OMIED/ALAMY STOCK PHOTO



▸ to hunt for this missing object. They sent out their letters in 1800. Meanwhile, before even receiving his invitation, Italian priest turned astronomer Giuseppe Piazzi spotted Ceres in the exact place Titius-Bode's law predicted on 1 January 1801.

Piazzi immediately announced his discovery in a letter to fellow Italian astronomer Barnaba Oriani, taking the precaution (as William Herschel had done before him) of claiming to have discovered a comet. Comet hunting by 1801 was a well-established and respectable astronomical activity; lots of people hunted for and discovered them. Planets were more unusual and to make such a claim could, if mistaken, have appeared arrogant and ungentlemanly. Piazzi did however hint at his suspicion, telling Oriani in his letter that while he thought he had found a comet, in fact, "it might be something better". News of this discovery passed across Europe and astronomers across the continent observed, checked and calculated its orbit, until it was eventually agreed that this was indeed a new – if rather small – planet. Piazzi could now name it, choosing the title Ceres, after the Roman goddess of agriculture.

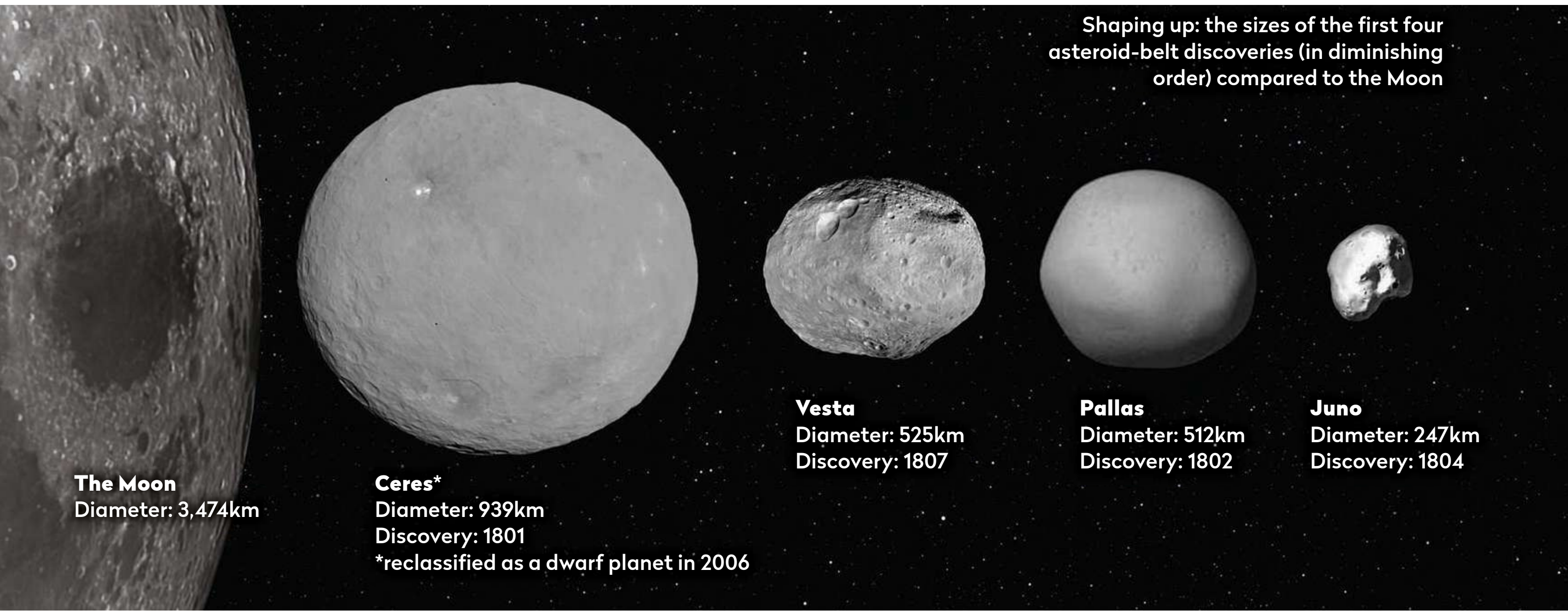
The search continues

Undeterred, the Celestial Police continued their search for unexplained objects along the ecliptic that were not stars. Then, over a year after they began, Heinrich Olbers, observing from the upper story of his home (which he'd turned into an observatory), discovered a second object, Pallas, on 28 March 1802. Olbers had actually been trying to take further observations of Ceres to help get a better understanding of this new planet when he came across Pallas. Once established as another planet (the term asteroid was still not in use), Olbers named it Pallas, after the Roman goddess of Wisdom.

Still the Celestial Police continued their searching and this time it was Karl Harding's turn to make a discovery, finding yet another body within the asteroid belt in 1804. When Harding discovered his asteroid, he named it Juno, after the highest Roman goddess.

▲ A Ceres of events: interest grew in the mysterious space between Mars and Jupiter, which culminated in the discovery of Ceres by Giuseppe Piazzi (inset)

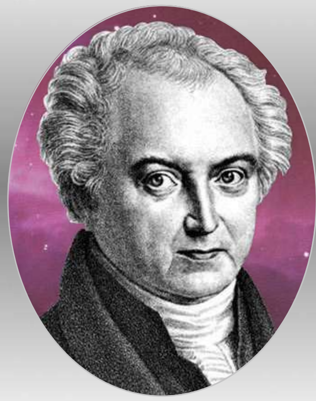
Far left: Piazzi used an instrument called a Ramsden Circle to find Ceres in 1801



Shaping up: the sizes of the first four asteroid-belt discoveries (in diminishing order) compared to the Moon

Meet the Celestial Police

The astronomers who embarked on a mission to find missing planets



Johann Schröter (1745–1816)
Johann Schröter was a lawyer turned astronomer. When William Herschel discovered Uranus, Schröter gave up law to devote all his time to observing. He is best known for his observations and accompanying drawings of the features of our nearest planets.

Baron Franz Xaver von Zach (1754–1832)
Originally from Budapest in Hungary, Baron Franz Xaver von Zach lived and worked in Paris, London and various European cities, sometimes as a private tutor, at other times a lecturer or in an Observatory. Towards the 18th-century's end, he helped put together the Celestial Police.

Karl Harding (1765–1834)
Karl Harding was employed as a tutor to Schröter's son, before being promoted to be an astronomical assistant and observer at Schröter's observatory in Lilienthal. Today, he is best known for his discovery of the third asteroid, Juno, in 1804, which he discovered at Schröter's observatory.

Heinrich Olbers (1758–1840)
Heinrich Olbers studied to be a physician before turning to astronomy. He discovered the asteroid Pallas in March 1802 and five years later discovered Vesta. Olbers believed the asteroid belt was formed when a single planet was destroyed in a collision with a comet.

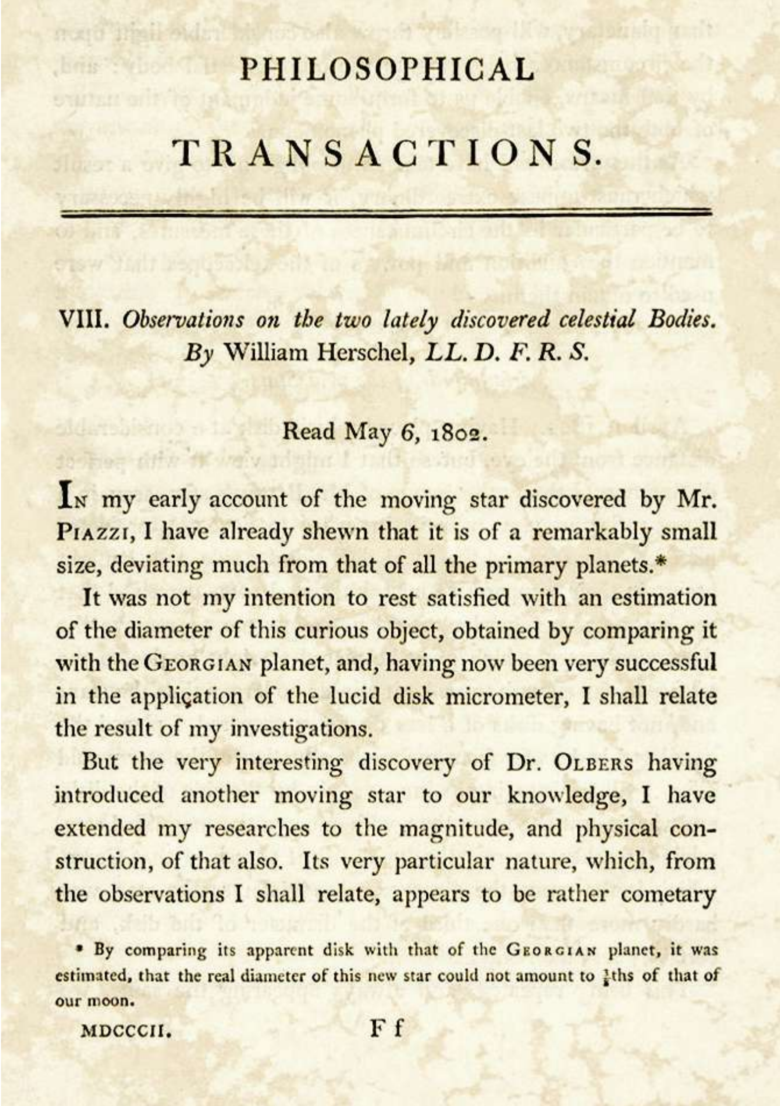
"The Celestial Police continued to search for asteroids for eight years after Vesta was discovered in 1807, but with no luck"

Three years later, in March 1807, Heinrich Olbers made his second discovery in the asteroid belt: Vesta. He chose the name, in keeping with the tradition so far established, of selecting the name of a Roman goddess. This time he chose Vesta, Roman goddess of the hearth, the home and of family. His search began when he started to hypothesise that perhaps Ceres and Juno were fragments of a former planet. This is the second now discredited theory in this story. Both Ceres and Juno, Olbers noted, were rather small to be the planet predicted by the Titius-Bode law. What if, he suggested in a letter to Carl Friedrich Gauss in 1802, "...Ceres and Pallas were fragments of a former larger planet that had been destroyed by colliding with a comet?" He went on, "Might we then still discover more pieces of this previously existing planet at its appropriate position?" The discovery of Juno seemed to confirm his suspicions, as did his own discovery of Vesta. (Today it's believed that the asteroid belt is more likely to be pieces of a planet that never formed thanks to the disruption of the formation process by Jupiter's gravitational pull.)

Meanwhile, as all these discoveries were being made and discussed in letters and society meetings across Europe, William Herschel was beginning to voice concerns. After all, his had been the first planet to be discovered since antiquity, and the first by a named discoverer. This small flurry of additional findings seemed (in his eyes) to rather dilute this achievement. In a rather long article in the *Philosophical Transactions of the Royal Society* (May 1802), he set out to analyse these new discoveries, determinedly not referring to them as planets. They were, he explained in his abstract, too small for that name, and rather oddly he preferred to call them stars. Towards the end of the paper, he proposed a new name, "asteroids", declaring that, "These bodies will hold a middle rank, between the two species that were known before," by which he meant planets and comets. It took a while, but by the mid-19th century that name had stuck.

The Celestial Police continued to search for asteroids for another eight years after Vesta's discovery, but with no luck. By 1815 they reluctantly concluded there were no more planets or their parts to be found in that part of the sky. It was to be 30 years before Karl Ludwig Hencke (and in time, others) would prove them wrong. ▸

NASA/JPL-CALTECH/PALERMO OBSERVATORY, NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA X 3



PHILOSOPHICAL

TRANSACTIONS.

VIII. *Observations on the two lately discovered celestial Bodies.* *By* William Herschel, *LL. D. F. R. S.*

Read May 6, 1802.

In my early account of the moving star discovered by Mr. Piazzi, I have already shewn that it is of a remarkably small size, deviating much from that of all the primary planets.*

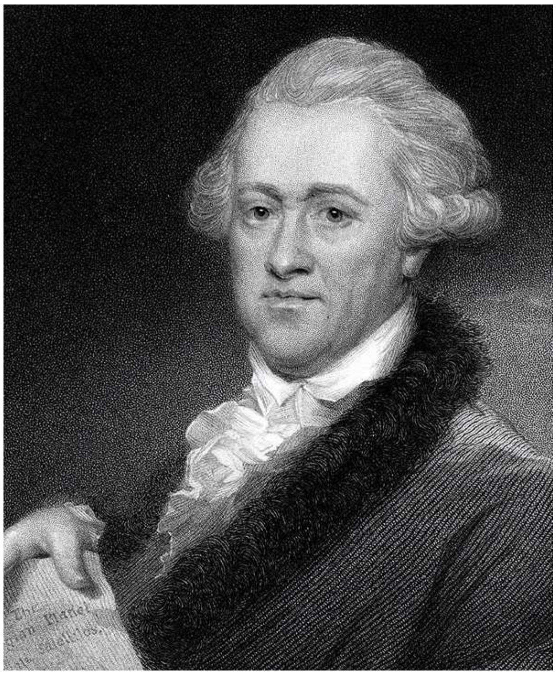
It was not my intention to rest satisfied with an estimation of the diameter of this curious object, obtained by comparing it with the Georgian planet, and, having now been very successful in the application of the lucid disk micrometer, I shall relate the result of my investigations.

But the very interesting discovery of Dr. Olbers having introduced another moving star to our knowledge, I have extended my researches to the magnitude, and physical construction, of that also. Its very particular nature, which, from the observations I shall relate, appears to be rather cometary

* By comparing its apparent disk with that of the Georgian planet, it was estimated, that the real diameter of this new star could not amount to $\frac{3}{5}$ths of that of our moon.

MDCCCII. Ff

◄ Challenging times: in 1802, writing in the *Philosophical Transactions of the Royal Society*, astronomer William Herschel (below) proposed the name 'asteroid'



► Of all the asteroids discovered both before and since, Vesta is the brightest and the only one bright enough to be seen with the naked eye thanks to its size and the nature of its surface. Over the years, astronomers have continued to study these asteroids, steadily getting closer and closer to measuring their various properties, including size and mass. In the 1880s, Edward Charles Pickering and his team at Harvard College Observatory measured Vesta's mean diameter to be approximately 513km, those measurements were refined in the 1980s and again in the 1990s, before being finally confirmed by NASA's Dawn mission (see box, opposite).

In 1966 Vesta became the first asteroid to have its mass determined, by using observations of its gravitational perturbations on fellow asteroid Arete. It was measured by Hans G Hertz from NASA's Goddard Space Center, who estimated Vesta's mass to be approximately 1.2×10^{-10} solar masses, an estimate that was further refined to be closer to 1.3×10^{-10} solar masses by the Dawn mission.

Vesta also has interesting physical characteristics, which again have been further studied and better understood thanks to NASA's recent Dawn mission. Vesta is the second most massive body in the asteroid belt (after Ceres) and has a 500km-wide crater on its surface (almost the width of the entire asteroid's diameter). The Dawn mission named this crater Rheasilvia after the mother of Romulus and Remus in Roman mythology.

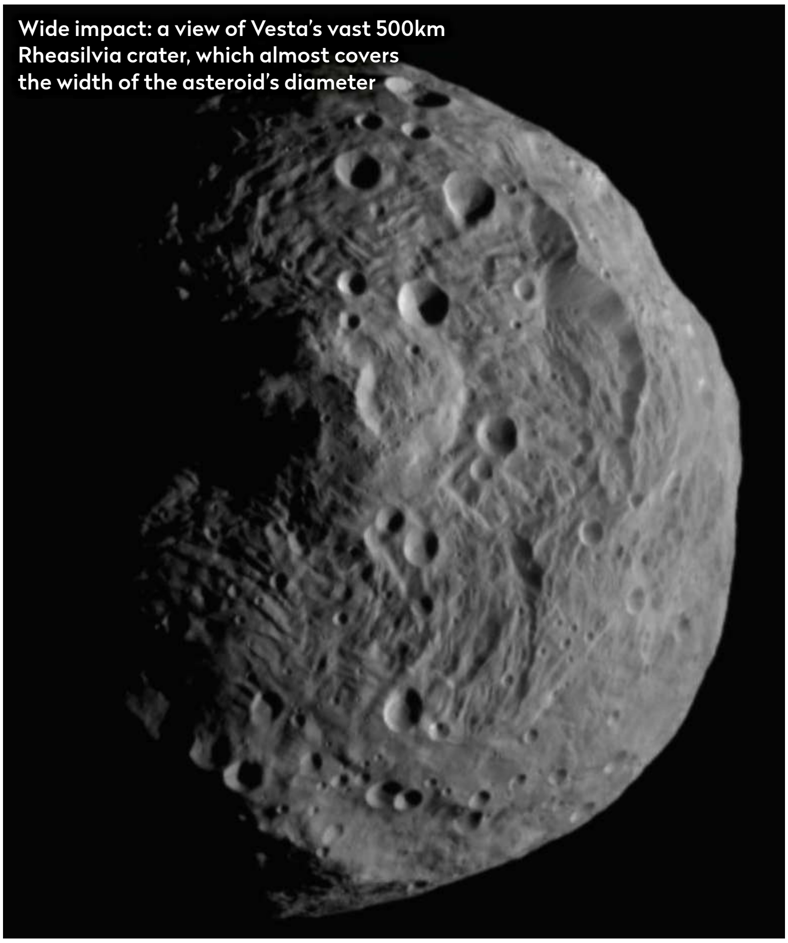
NASA's Dawn mission was the result of many years of planning and a series of false starts. Proposals had been made since the early 1980s to send a spacecraft to Vesta to study it in more detail, not just by NASA but by ESA and the Soviet Union too, but it wasn't until the Dawn mission was launched in 2007 that those ambitions were finally realised. The mission set out to visit both Vesta and Ceres to learn more about these objects, the asteroid belt and the formation of our Solar System. In the process they were able to confirm or improve on earlier studies of these space rocks.

A people's story

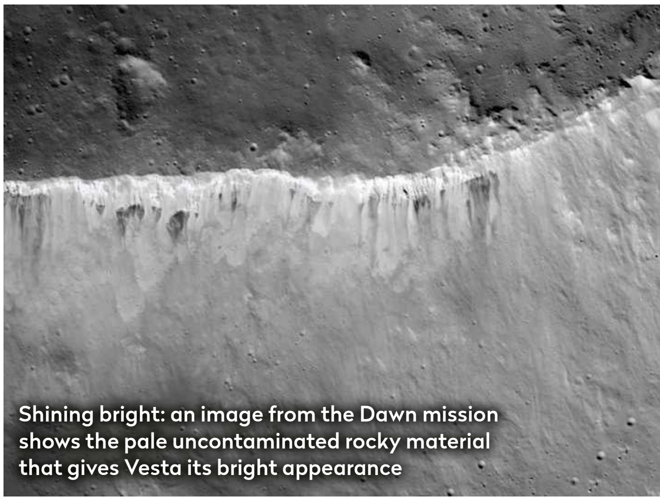
The story of Vesta is one that allows us to see science for the human process that it is. It is fallible, it makes mistakes, but keeps going, and in the end finds something wonderful. Titius and Bode might not have been right about their law (it falls down at Neptune whose orbit doesn't fit its rules) and Olbers might not have been right about how he thought the asteroid belt was formed. When he proposed the term 'asteroid', Herschel may have

Emily Winterburn is author of *The Quiet Revolution of Caroline Herschel: The Lost Heroine of Astronomy*

"Vesta is the only asteroid that is bright enough to be seen with the naked eye thanks to its size and the nature of its surface"



Wide impact: a view of Vesta's vast 500km Rheasilvia crater, which almost covers the width of the asteroid's diameter



Shining bright: an image from the Dawn mission shows the pale uncontaminated rocky material that gives Vesta its bright appearance

only thinly disguised his jealousy that others could also discover planets. And more recently, since the 1980s astronomers might have tried and failed for nearly four decades before finally getting a space mission to visit Vesta. But rather than diminishing the achievements, all these setbacks only make our knowledge and appreciation of this celestial body greater. On 4 March, as we go out to take a look at this bright asteroid, spare a thought for all those failures: taken together they have made it possible for us to know what we're looking at.

To read more about Vesta, see pages 47, 53 and 55

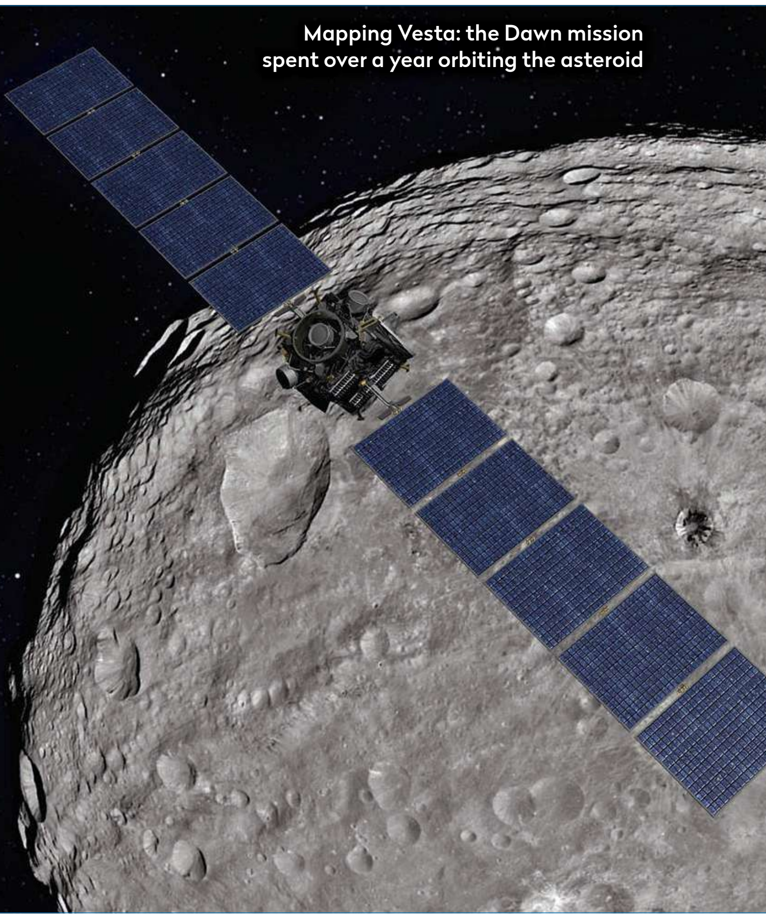
Inside the asteroid belt

NASA's Dawn mission explored the rocky worlds of Vesta and Ceres

By getting up close to asteroid 4 Vesta, the Dawn mission unlocked clues about the early years of the Solar System.

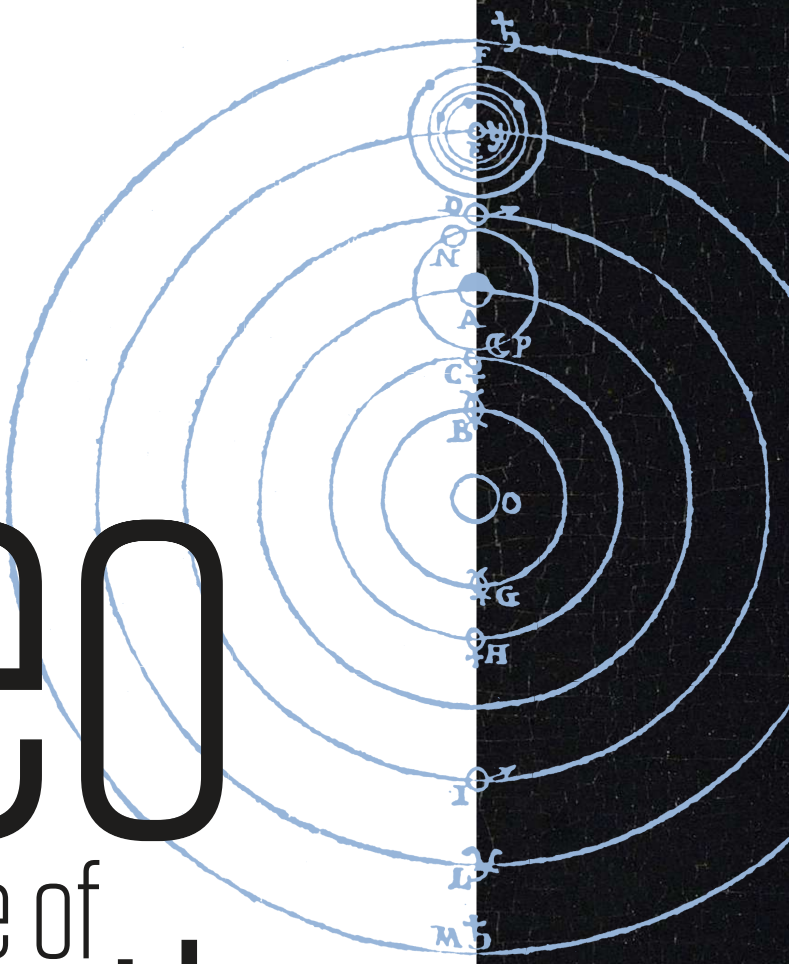
NASA launched the Dawn mission in 2007 with the aim of finding out more about Vesta and Ceres. These two large asteroid belt objects were chosen because they were already known to be very different from one another. Together, they represent the materials that existed at the beginning of our Solar System (in the first 10 million years or so). While Vesta is similar to the rocky worlds of the inner Solar System, Ceres shares more in common with the icy moons of the outer Solar System. By studying the geology and composition of both, we can learn not only about our asteroid belt, but about Solar System's origins.

Dawn reached Vesta first, in July 2011, and began its orbit of the giant asteroid. It found that Vesta has two large impact basins and linked some of the debris from those impacts with meteorites found on Earth. Dawn also mapped Vesta's geology, composition and cratering record and took readings that could help us understand the asteroid's internal structure. After orbiting Vesta for over a year, Dawn moved on to Ceres, orbiting the dwarf planet in 2015. The mission officially ended in October 2018.



Mapping Vesta: the Dawn mission spent over a year orbiting the asteroid

ILLUSTRATION



Galileo and the nature of observation

In March 1610 Galileo's *Sidereus Nuncius* was published, the first scientific work based on the use of a telescope. Philosopher **Toby Friend** looks at the questions it still raises about how we see the natural world

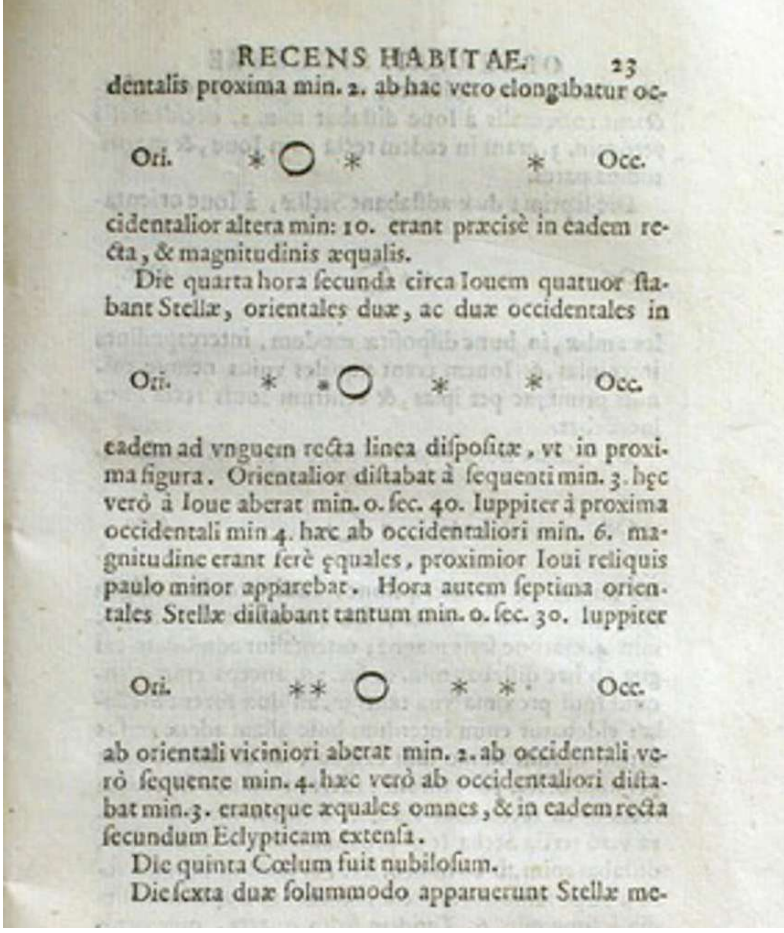
IMAGNO/CONTRIBUTOR/GETTY IMAGES, PHOTOS.COM/ISTOCK/GETTY IMAGES

When we look up at the sky through a telescope it's easy to suppose that we can learn how the Universe appears to us untainted by theoretical and philosophical assumptions. After all, it's not like we need to know any specific theory of cosmology to operate a telescope or to record what we see. And what could philosophy possibly have to do with it? But in fact, things are not so straightforward. The relationship between what appears to us in the night sky and what our theories say about those appearances is riddled with questions that continue to puzzle philosophers and thinkers. It may turn out that what we can learn about the Universe depends on all sorts of factors we are not typically aware of.

A little over 400 years ago, in the spring of 1610, Galileo was staring up at the heavens through his latest apparatus. Telescopes of 2x magnification had been in existence for only a couple of years and the polymath from Pisa had now built himself one 10 times as powerful. With that extra magnification, and a keen eye, Galileo was the first to observe the craters of the Moon and four of Jupiter's moons, which he detailed in his book *Sidereus Nuncius* ('The Starry Messenger'). Though he refrained from claiming so in the publication, he took the findings to support Copernicus's heliocentric model of the Solar System by bringing the perfection of celestial bodies into question and suggesting that at least some things other than Earth were orbited (in this case, Jupiter). This got him into trouble with the Catholic Church.

From a modern philosophical perspective what is so fascinating about the Church's 'Galileo affair' is not so much the evidence for heliocentrism, but what the Church's complaint was really about. In 1616 Galileo was instructed by Cardinal Bellarmine ▸

Heavens above: a portrait of Galileo from around the time he wrote *Sidereus Nuncius* in 1610. His illustrations (see inset) showed that objects other than Earth are orbited by moons



RECENS HABITAE. 23

dentalis proxima min. 2. ab hac vero elongabatur oc-

Ori. * O * * Occ.

cidentalior altera min: 10. erant præcisè in eadem re-
cta, & magnitudinis æqualis.

Die quarta hora secunda circa Iouem quatuor sta-
bant Stellæ, orientales duæ, ac duæ occidentales in

Ori. * * O * * Occ.

eadem ad vnguem recta linea dispositæ, vt in proxi-
ma figura. Orientalior distabat à sequenti min. 3. hęc
verò à Ioue aberat min. o. sec. 40. Iuppiter à proxima
occidentali min 4. hæc ab occidentaliori min. 6. ma-
gnitudine erant ferè ęquales, proximior Ioui reliquis
paulo minor apparebat. Hora autem septima orien-
tales Stellæ distabant tantum min. o. sec. 30. Iuppiter

Ori. ** O * * Occ.

ab orientali viciniori aberat min. 2. ab occidentali ve-
rò sequente min. 4. hæc verò ab occidentaliori dista-
bat min. 3. erantque æquales omnes, & in eadem recta
secundum Eclypticam extensa.

Die quinta Cœlum fuit nubilosum.

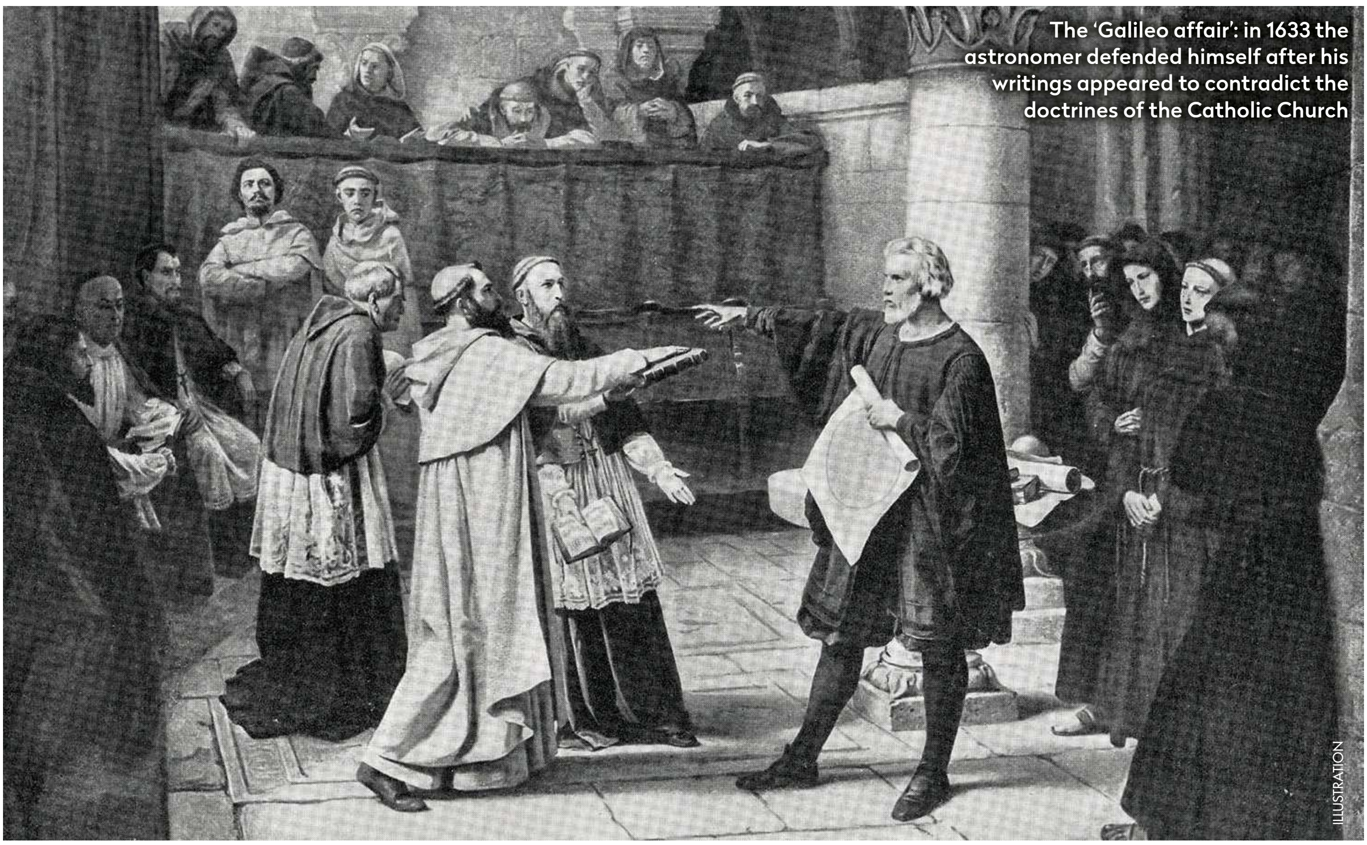
Die sexta duæ solummodo apparuerunt Stellæ me-

▲ A page from the first edition of *Sidereus Nuncius* shows Galileo's drawings of the moons around Jupiter

▸ "...to abandon completely... the opinion that the Sun stands still at the centre of the world and the Earth moves". The instruction was not, however, to abandon heliocentric models as a useful predictive tool. The Cardinal had pointed out once before that it is one thing to show that by merely supposing Earth orbits the Sun one can calculate accurately where and when other heavenly bodies will be in the night sky, but it is another thing entirely to make the sacrilegious declaration that, "In truth, the Sun is at the centre and the Earth in heaven". His concern was that Galileo was promoting the heliocentric model as something to be believed rather than, as he put it, a mere contrivance used to "save the appearances".

Lines of scientific enquiry

There is a venerable history to the idea that scientific enquiry should aim only to 'save the appearances'. The phrase has its roots in the musings of ancient Greek philosophers and stargazers, and has been a hot topic among scientifically-minded thinkers ever since. In 1908, French physicist and philosopher Pierre Duhem suggested that logic was on the side of Bellarmine rather than Galileo. His thinking was that Bellarmine understood that science is all about developing theories that help us to make accurate predictions and not one which is to be evaluated for its plausibility. The so-called 'logical positivists' of the early to mid-20th century took a similar view, arguing that claims about the world which extend beyond what is directly observable are unjustifiable. Contemporary philosopher Bas van Fraassen argues that, "Science aims to give us theories which are empirically adequate". In other words, science aims only to predict what's perceptible, nothing more.



The 'Galileo affair': in 1633 the astronomer defended himself after his writings appeared to contradict the doctrines of the Catholic Church

Galileo the polymath

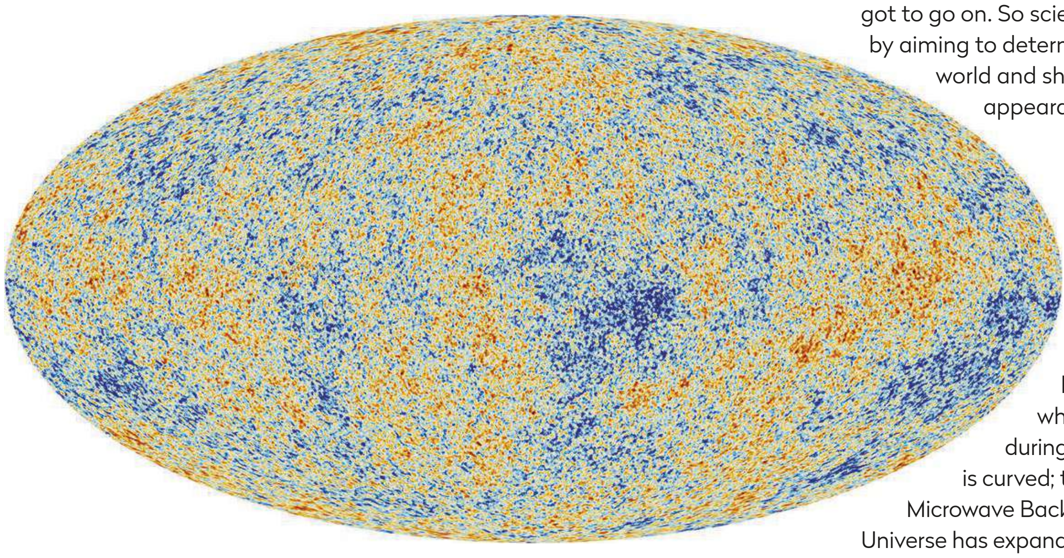
His contribution to physics, engineering and philosophy was as profound as to astronomy

Galileo may be most famous for the astronomical observations which led to his outspoken views in defence of heliocentricism. But this was not his only contribution to science, nor even the most important. In fact, Galileo was the first to theorise about many physical phenomena which form the basis of contemporary physics. These included the constant period of a pendulum, the relationship between the pitch of soundwaves and their frequency, and the independence of nature's laws from the observer's own frame of reference (a form of relativity).

Galileo was also an impressive inventor, making significant contributions to the development of the navigational compass, the thermometer and, of course, the telescope, whose name was coined to refer to Galileo's own instruments. And that's not all, Galileo wrote a highly influential treatise on the method of scientific investigation, arguing that the laws of nature are 'written in the language of mathematics' and that claims should be based on experiment rather than religious dogma.

Despite this, one of his most famous defences for his claim that all bodies fall at the same rate (regardless of their weight) was purely logical. He reasoned that if two different weights were connected they could neither sensibly be understood to fall faster nor slower on average than when unconnected. He deduced, therefore, that they must fall at the same rate. Philosophers still debate whether this argument actually justifies the conclusion.

▸ A 19th-century model of a pendulum clock that took inspiration from an idea that Galileo had just before his death



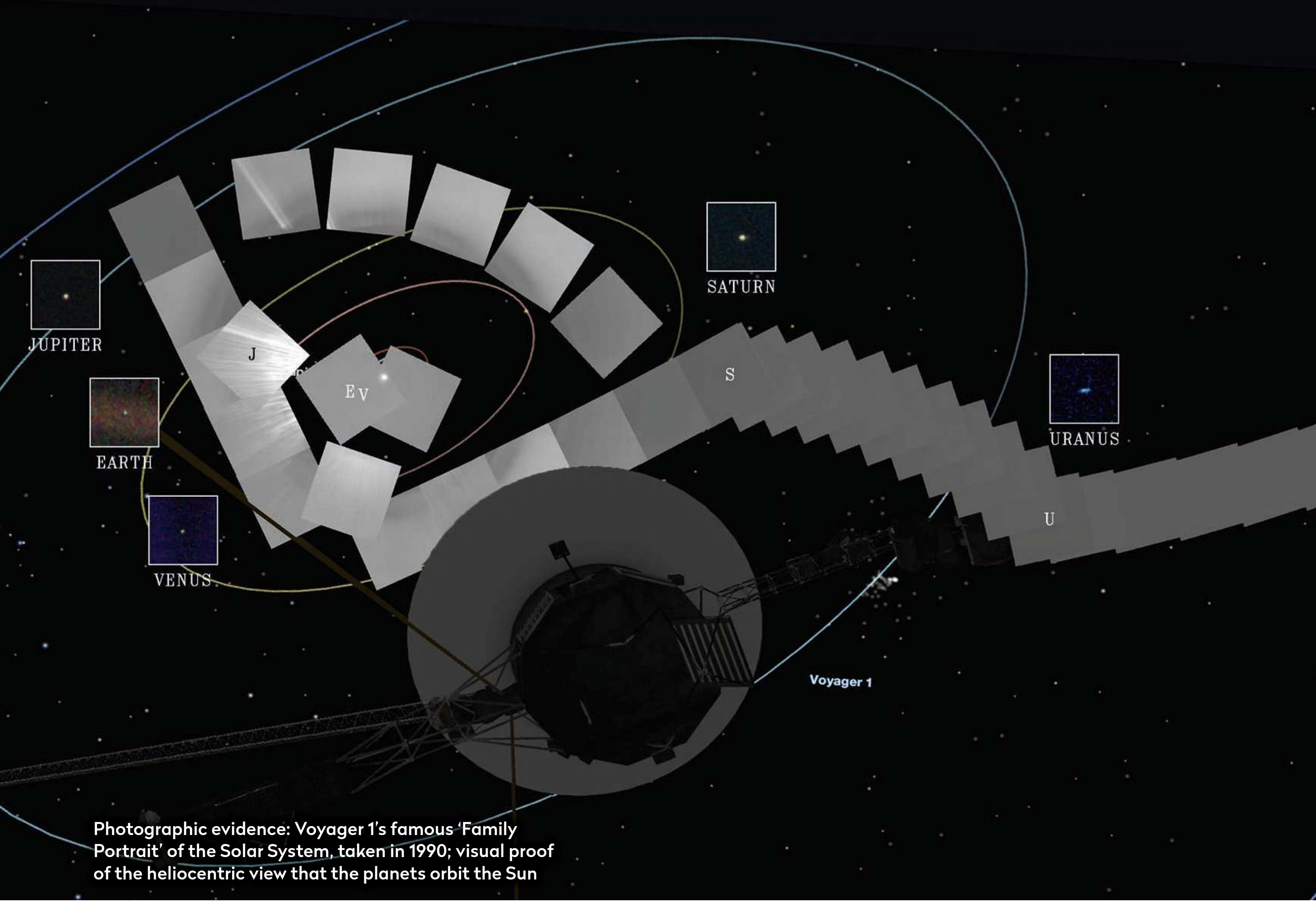
▴ Modern methods: by using the Cosmic Microwave Background (CMB) – radiation left over from the Big Bang – scientists can look at how the Universe has expanded

If these thinkers are right, what we can learn when looking through a telescope is nothing more than how things look to us. One can sympathise with the general idea. A well-known anecdote has one philosopher (Wittgenstein) asking another (Anscombe) why so many once believed the Sun orbits Earth. "It looks that way," came the response; to which the first replied, "And how would it have looked if the Earth was rotating?" The thought was that the appearances – the way things look – don't on their own tell us what to believe. But in empirical science, the way things appear to us are all we've got to go on. So science shouldn't overreach itself by aiming to determine anything more about the world and should stick to merely 'saving the appearances', just as Bellarmine argued.

Different views

Nevertheless, surely we want to say that Galileo was justified in believing that heliocentrism was true. Today we're constantly claiming to learn facts about the world on the basis of telescopic observation: where stars appear near the Sun during eclipses confirms that space is curved; the detection of the Cosmic Microwave Background (left) confirms that the Universe has expanded; the observation of galaxies' rotation confirms the existence of dark matter; and so on. If Bellarmine, Duhem and the logical positivists had their way, we would have had to wait until 1990, when Voyager 1 sent us its 'Family Portrait' of the Solar System, before we were permitted to claim that heliocentrism was believable. That was our first photographic image of the Sun's position in relation to the planets. By contrast, most modern scientists tend to be 'realists'. They take observations, images, computer read-outs and data to confirm our belief in the truth of theories which go beyond how things look.

So what you think you can learn by looking through a telescope depends, for one thing, on whether you ▸



Photographic evidence: Voyager 1's famous 'Family Portrait' of the Solar System, taken in 1990; visual proof of the heliocentric view that the planets orbit the Sun

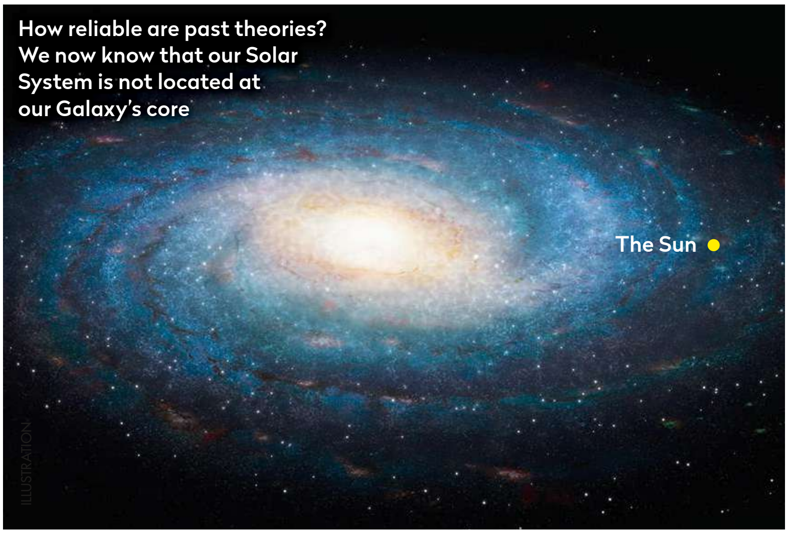
▸ are a scientific realist or not. Settling the matter is not easy; on the one hand, the success of scientific theories through the ages can seem to suggest that they must be more than mere inventions for the sake of predicting how things will look. As philosopher Hilary Putnam remarked in 1975, realism "...is the only philosophy that doesn't make the success of science a miracle." On the other hand, it can hardly be denied that even our most successful scientific theories seem destined to be falsified in the end. We knew by Newton's time, for example, that heliocentrism as it was conceived by Galileo wasn't quite right. The Sun isn't exactly at the gravitational centre of the Solar System. And Galileo refused to believe the planets orbit in ellipses. More recently, we've learned that the Solar System isn't even at our Galaxy's centre. These developments should cast into doubt the idea that even today's physical theories are perfectly true. But they also bring into question the realists' view that truth is what astronomers should be searching for in the first place. If all theories are destined to be superseded, why ever believe them?

Keeping an open mind

But perhaps we needn't settle the matter either way. Both realists, like Galileo, and 'anti-realists', like Bellarmine, rely on the idea that there are at least 'appearances', which can be either saved or gone beyond. That's questionable in itself. It's now suspected that Galileo's guesses about the size of stars was confounded by the Airy discs (diffraction patterns) produced in his telescope around star images. If that's right, the stars weren't appearing directly to Galileo at all. And nowadays, hardly any astronomy is conducted via direct observation.

At a minimum, telescopes bring the light from the stars onto our eyes via a series of mirrors and lenses. Large telescopes, such as Hubble, record data on a computer from much more of the electromagnetic spectrum than we can perceive. Astronomers must manipulate that data in order to get an idea of what Hubble is pointing at. Given the indirectness of our astronomical observations, where should we say the appearances lie? Is it on the outer lens of our scopes or on some internal mirror? In the eyepiece or on the lens of our eyes? Any choice seems arbitrary. But if we

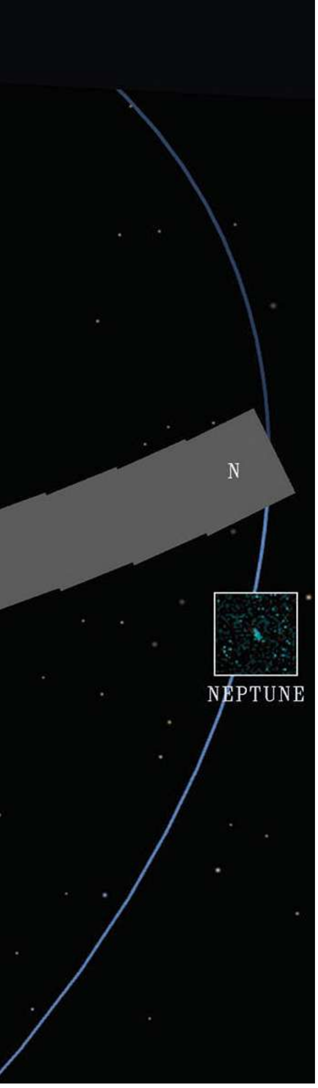
Toby Friend is a philosopher working at the University of Bristol on the Metaphysical Unity of Science Project, funded by the ERC (grant 771509)



How reliable are past theories? We now know that our Solar System is not located at our Galaxy's core

ILLUSTRATION

NASA/JPL-CALTECH, SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO



can't say where the appearances are, then it makes little sense to claim that the aim of scientific theories is either to save them or go beyond them.

Challenging perceptions

An alternative both to realism and anti-realism is to admit that theory and appearances are inextricably tied together. By the 1960s, historians and philosophers like Norwood Russell Hanson, Paul Feyerabend and Thomas Kuhn had started to notice that scientific observation is 'theory-laden' – bound up with theoretical knowledge which must be understood in order to make any sense of the way things look. This explains how NASA knew from Hubble's first blurry images that something was wrong with it. Given what we already knew, the Universe shouldn't have looked like that. And even our use of domestic scopes is theory-laden. For example, we know to wait for cloudless evenings, to adjust the focus or collimate the optics to compensate if the image we're seeing isn't sharp. Crucially, Galileo understood many of these things, but not all; part of his trouble was persuading others to trust in an instrument whose operation no optical theory at the time could fully explain.

So, what can you learn when looking up at the sky through a telescope? Clearly, it depends on how much theoretical knowledge you're lucky to be laden with: about the night sky and how far away the objects you want to look at are, about optics, about the construction of the scope and about your own perceptual abilities. Imagine how hard it would be to use one if you didn't know these things! But what you can learn also depends on whether it's possible, as realists believe, to know anything beyond how things appear to you. Anti-realists think it's not possible because that's not science's job. Others think it's not possible because there isn't anything precise to the notion of 'how things appear to you' independent from what you already believe. Philosophers, astronomers and science historians will continue to debate these issues for a long time; but they are things for us all to ponder as we gaze up on the next clear night.

A message from the stars

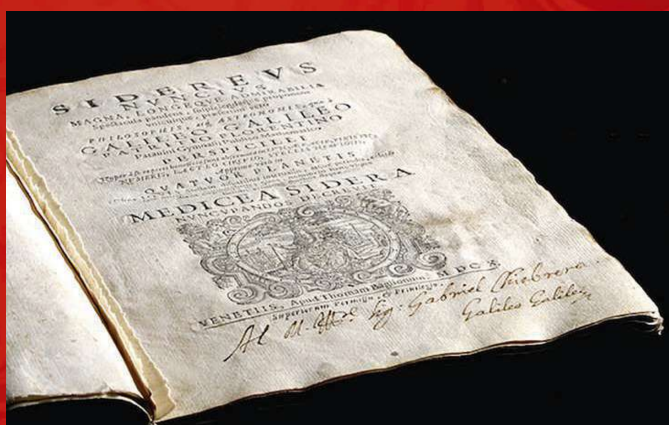
Galileo's *Sidereus Nuncius*, published over 400 years ago this month, launched his career and changed our view of the natural world forever

Sidereus Nuncius, usually translated as 'The Starry Messenger', went on sale to the public on 13 March 1610 and news of its contents spread fast. Although it presented no revolutionary scientific theory (when compared with Galileo's other great scientific contributions) it had expressed within it significant observations of astronomical phenomena that clashed with the orthodoxy. Of particular note were Galileo's claim to have seen craters on the Moon and four moons orbiting Jupiter.

The initial reception of the book divided opinion. In one famous case a critic suggested that Galileo was no more believable than someone claiming to have squared the circle (a literally impossible geometric task) or to have manufactured a philosopher's stone (which turns any metal into gold). Others gave Galileo the benefit of the doubt. For instance, the astronomer Johannes Kepler professed that he could see no reason why he should "not believe a most learned mathematician, whose very style attests the soundness of his judgement". Though Kepler had a vested interest since Galileo's claims indirectly supported Kepler's favoured heliocentric model of the Solar System.

Two reasons preventing the book's unanimous endorsement were that no one at that time had a telescope as powerful as Galileo's, and the fact that Jupiter went out of sight for the late spring months. Nevertheless, by the end of the year, Galileo's 'starry message' had been widely verified, making Galileo a celebrity and telescopes a desirable item from then on.

Turn the page to find out how to make a telescope similar to the one Galileo used for yourself ▶



▶ **Landmark publication: _Sidereus Nuncius_ helped to increase interest in telescopes**

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Make your own Galilean telescope

Construct your own home-built version of Galileo's famous 1609 telescope

More ONLINE

Download plans and additional photos for this project. See page 5 for details

Talking point: the telescope offers an insight into a piece of astronomical history

This month's project is a working replica of a very famous instrument. In 1609 Galileo designed and built his first telescope. This could magnify approximately 8x, but he quickly improved it to magnify objects nearly 21x. The aperture was small and the field of view was very restricted, but despite these limitations, in the following year Galileo published some exciting celestial discoveries in *Sidereus Nuncius*. These included craters on the Moon, the phases of Venus and three of the largest moons of Jupiter. He also observed the unusual shape of Saturn, but was not able to interpret that this was due to the presence of its rings.

We thought it would be interesting to build a telescope based on this instrument. Although ours is not intended to be an exact replica, we have made use of similar construction techniques and have also chosen lenses with similar specifications, so our views should be approximate to those seen 411 years ago!

Making a replica

The original telescope resides in the Museo Galileo in Florence, Italy. It consists of a main tube with separate housings at either end for the objective lens and the eyepiece. These can slide in and out to adjust the focus (longer for close objects). The tube is formed by long, thin strips of wood joined together with a resin and is covered with red leather decorated in gold. In our telescope we have used similar strips of wood and filled the gaps with wood filler. After rubbing down, we used a sticky-backed vinyl with a leather effect as a finish (leatherette) and decorated it with gold paint.

The original objective lens is a plano-convex type (flat one side with a bulge on the other), with the convex side facing outwards. Its specifications include a diameter of 37mm, an aperture of 15mm and a focal length of 980mm. For our project we found a very reasonably priced 50mm-diameter double convex lens with a focal length of 1,000mm, and we reduced the aperture to 15mm with a 'lens ring' to replicate the original.

Galileo's original eyepiece was lost and was replaced in the 19th century by a biconcave eyepiece (curved inwards on both sides); with a diameter of 22mm and a focal length of –47.5mm (a diverging lens). We chose a biconcave lens with a 50mm diameter (again, we reduced the aperture) and a focal length of –50mm. This results in a magnification of 20x; the original telescope was 20.6x so we are very close, although our tube is about 25mm longer.

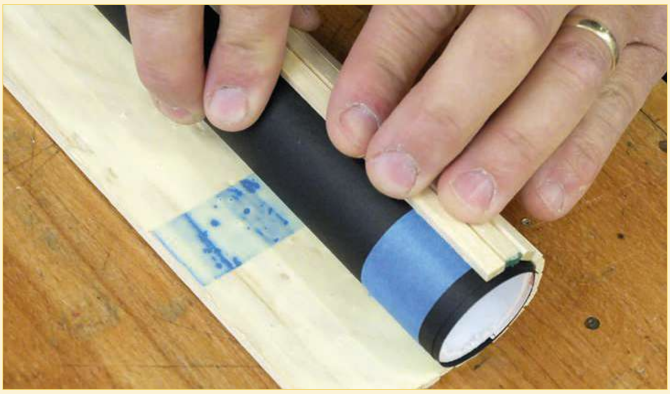
We mounted our finished scope on a simple tripod to test it, and although it is tricky to point it without a finderscope, we eventually managed to observe some features on the Moon and also saw a coloured (but blurry) disc of Mars. Throughout the project, it was awe-inspiring to consider how so much pioneering work was achieved with such an instrument!

Mark Parrish is a bespoke designer. See more of his work on his website: **buttondesign.co.uk**

What you'll need

- Marking-out tools (including a ruler, compasses and a pencil), a coping saw, a small handsaw, a craft knife and safety mat, a coarse file and sandpaper
- Materials include 30 lengths of 3mm x 6mm x 900mm wood (from a model shop), or similar small strips to make tubes, and approximately 1m-length of 32mm (1.25-inch) PVC waste pipe, plus leatherette to cover tubes
- Sundries include two educational-grade lenses (50mm diameter with a focal length of 1,000mm; and 50mm diameter with a focal length of –50mm), wood filler (two-part, resin-type), wood glue and masking tape, black card (three A4 sheets), and a small piece of 3mm plywood (approximately A4-size) or thick card for lens tube rings.
- For the finish you'll need matt black spray paint for inside of tubes, red spray to decorate, gold paint for a patterned finish.

Step by step

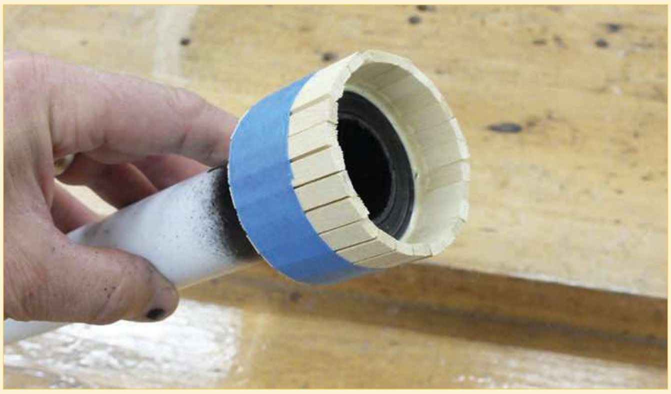


Step 1

Calculate the length of your main tube by adding the focal lengths of the lenses together (remember, one is negative!) and subtracting 100mm (ours was 1,000mm – 50mm – 100mm = 850mm). Use a fine-toothed saw to cut the sticks to length.

Step 2

Tape sticks together and apply glue to the surface. Wrap your PVC tube in an offcut of leatherette (don't remove the sticky back) so its diameter is a bit larger, and wrap black card round it. Wrap the glued sticks round the black card layer and hold with tape.



Step 3

When the glue has dried, fill all the gaps with wood filler. When this has set, file down and sand any raised areas. Sand the ends before pushing out the PVC tube and leatherette, leaving a neat, black card lining; the tube should be strong and rigid.

Step 4

Use a similar process to make the two lens holder tubes; there are two plywood rings which are glued to the PVC tube. Make sure there is space for the lens and a plywood 'lens ring' in the recess. Sticks and filler are used as before.

Step 5

After spraying the insides and ends of the tubes matt black, add pieces of leatherette to decorate. Check the lens tubes slide inside the main tube. We masked off some sections and sprayed them red and made a rubber stamp to print on gold decoration.

Step 6

When everything is dry you can install the lenses. We used a very small dab of hot glue to hold them in and then pushed in the leatherette-covered lens rings. Once completed, you will need to experiment by sliding the eyepiece holder in and out to focus.

Introduction to Astrophotography

The fundamentals of astronomy for beginners

EXPLAINER

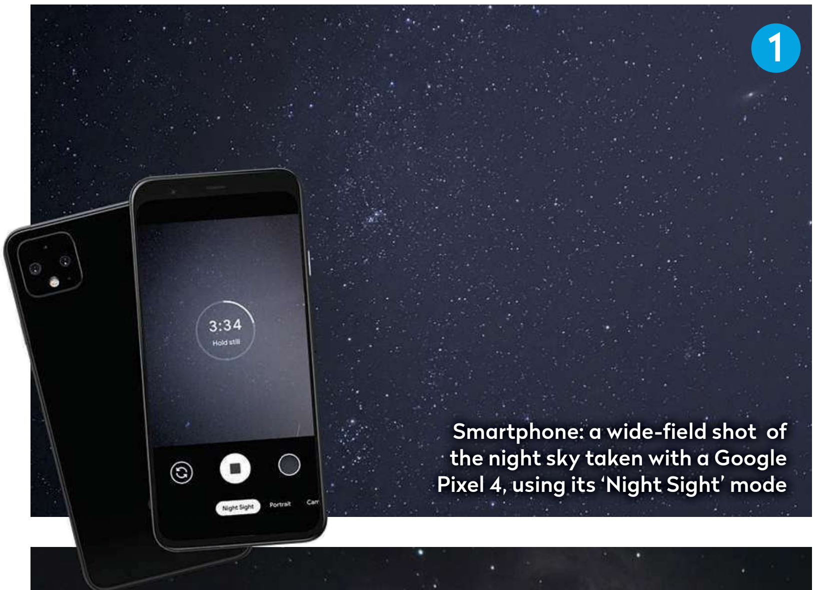
Get to know the different types of astro cameras

Charlotte Daniels introduces them and recommends the most suitable types of imaging

Astrophotography has become increasingly popular and thanks to modern technology, these days we don't need enormous budgets to get great images; even smartphone cameras can give impressive results.

The main consideration when selecting your astro camera is whether you wish to pursue wide-field, planetary, or deep-sky imaging. Typically, any device used for night-sky imaging will need to perform long exposures, have remote shutter capability and ISO control (to alter sensitivity to light).

Here we're going to run through the most popular cameras for astro imaging, pointing out strengths and considerations. We begin with a type of camera that many people will have with them most of the time.



Smartphone: a wide-field shot of the night sky taken with a Google Pixel 4, using its 'Night Sight' mode

1 Smartphones

Many smartphones can perform entry-level astrophotography, while some offer the ability to take long exposures, meaning you can pick up Milky Way details or star trails. You can also hold smartphones up to a telescope eyepiece to take pictures, or use a smartphone adaptor (see boxout, right). This enables lunar and planetary imaging, but it's difficult to get sharp images. Although some smartphones have multiple cameras installed, these are tricky to line up to eyepieces. In a nutshell, smartphones are not dedicated astrophotography products and don't offer the exposure control of a DSLR camera.

Best suited for: Star trails, Milky Way and general wide-field imaging

Limitations: Deep-sky photography

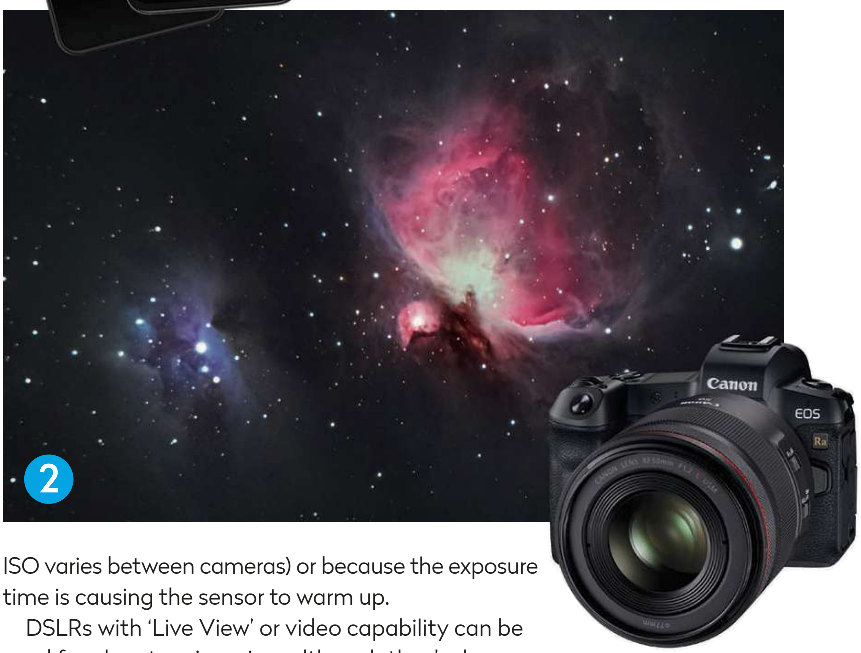
Accessories: Tripod; telescope adaptor

2 DSLRs

DSLRs (Digital single-lens reflex cameras) are good all-rounders. Because you can alter the ISO level and manage exposure lengths, these cameras are easily adapted for many astronomy targets. Increasing the ISO setting ensures a DSLR can pick up details from deep-sky objects, including nebulae, but if this is coupled with a long exposure time there can be an issue with noise (unwanted artefacts) creeping in, which can be because the ISO is too high (the best ISO varies between cameras) or because the exposure time is causing the sensor to warm up.

DSLRs with 'Live View' or video capability can be used for planetary imaging, although they're less efficient at cutting through atmospheric distortion than a planetary camera.

Some astro imagers modify a DSLR by removing the infrared (IR) filter, which makes it more sensitive to nebulae. A modified DSLR also allows narrowband filters to be used, which improve image details.



▲ DSLR: the Orion Nebula taken with Canon's EOS Ra mirrorless DSLR, which has a modified IR filter

© GOOGLE X 2, PAUL MONEY, ©CANON, CHARLOTTE DANIELS/CHRIS GRIMMER, @THESHED/PHOTOSTUDIO X 2, GARY PALMER, PETE LAWRENCE

Planetary camera: the lunar crater Tycho, as captured by an Altair GPCAM2 327C coupled with a Sky-Watcher 150 ED refractor

CMOS: the galaxy pair M81 (left) and M82, taken with a ZWO ASI 1600GT CMOS camera, connected to a SharpStar 15028HNT telescope

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

Best suited for: Wide-field, lunar and deep-sky imaging
Limitations: Exposures lasting over ~5 minutes, planetary imaging
Accessories: Tracking mount; intervalometer (remote shutter release cable)

3 Planetary cameras & webcams

Planetary imaging requires a telescope and you'll find that reflectors are most suitable because of their long focal lengths. If a planetary camera is also coupled with a 2x Barlow lens you'll be able to achieve the magnification required for planetary detail, while the camera's high frame rate will allow you to cut through atmospheric turbulence.

You'll require a laptop to run these cameras and, as you're viewing an object up close, a solid tracking mount is also needed, which allows you to keep the planet central in the field of view. When it comes to deep-sky imaging, planetary cameras have small sensors which means they're not always suited.

It's also possible to modify an off-the-shelf webcam for planetary imaging, so that it fits into the eyepiece holder of your telescope (see the box below for more details).

Best suited for: Lunar and planetary imaging
Limitations: Deep-sky objects and wide-field imaging
Accessories: Laptop; 2x Barlow lens; processing software (eg RegiStax)

4 CMOS & CCD cameras

CMOS and CCDs are 'dedicated astrocams', which are designed to be fitted to a telescope. Each comes in 'colour' – for RGB (Red, Green and Blue) imaging – or 'mono' variants. Mono cameras require the use of colour or narrowband filters.

CCD (charge-coupled device) cameras are suited for long-exposure photography (10-plus minutes per frame) because they have 'set-point' cooling systems that keep the sensor temperature constant, which is known as 'active' cooling. CMOS sensors perform better with shorter exposures and come as either actively or 'passively' cooled.

Laptops are needed to run either device. To maximise CCD exposure times, additional accessories – including guiding equipment and software – are often required. Using these cameras can be a steep learning curve, so it's best to build up to it gradually.

There are adaptors available that fit these 'astro cams' to DSLR camera lenses, which allows you to use them for wide-field deep-sky imaging.

Best suited for: Deep-sky imaging
Limitations: Milky Way and wide-field imaging
Accessories: Laptop; telescope; guide equipment and software

Attach a smartphone to a scope's eyepiece holder with an adaptor

Astrophotography with a telescope

Linking your astro camera is easy, here's the kit you'll need

You can go far with astrophotography by using a DSLR and lenses, but for a deep-sky object or planetary photography the addition of a telescope to your setup will widen your options. Your target will appear larger, allowing more detail.

Smartphones can be fitted to a telescope eyepiece holder via an adaptor; you just need the right one for your model. Meanwhile, to attach a DSLR you will need a T-ring and nosepiece; the T-ring fits to the camera like a lens. For example, if you are using a Canon DSLR, you'll need a Canon-fit T ring. Meanwhile, the nosepiece is either 2-inch or 1.25-inch and you'll find that most telescopes take either diameter.

If you are using a webcam, you'll need to consider modifying it to fit to the scope eyepiece holder. This often involves stripping the webcam down to rehouse it in suitable casing. How difficult and effective this is will depend on the model. If you are using a 2x or 3x Barlow lens and a reflector, you'll pop the Barlow into the eyepiece barrel before attaching your webcam.

Designated planetary cameras, CCD and CMOS devices, come with a nosepiece attachment that fits to your scope.

Take the perfect astrophoto with our step-by-step guide

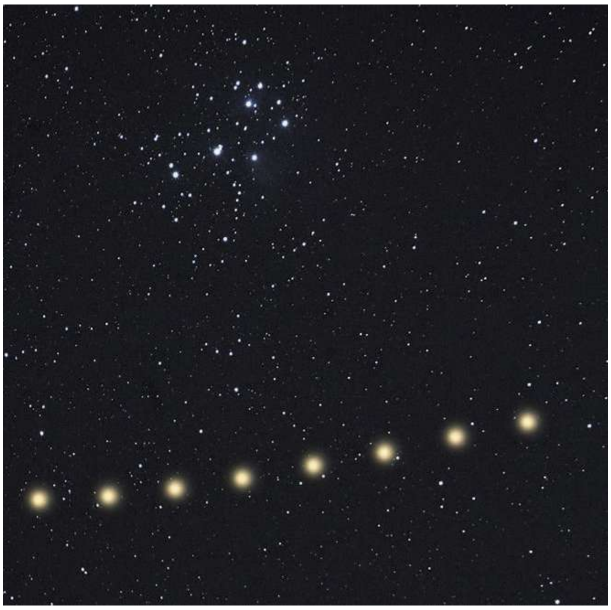
ASTROPHOTOGRAPHY CAPTURE

Recording an object in motion

Create a composite image that shows the movement of an object over several nights

How many times have you seen things move in the sky? Ignoring artificial satellites, there isn't much that you can look at directly and see move. Meteors and the aurora obviously fit into this category, but outside Earth's atmosphere, there's little else. Rare examples include bright close-pass asteroids or highly energetic coronal mass ejections from the Sun viewed through a hydrogen-alpha filter.

This month there are two examples of movement which, to be frank, you can't see in real time. Mars passes below the beautiful Pleiades open cluster at the start of the month (right) while Vesta, bright as it nears opposition, appears to move through Leo right across March. So how can you show they actually move?



▲ **On target: see if you can capture Mars as it moves below the Pleiades to make a composite image**

On long time exposure shots of the stars, it is sometimes possible to see asteroid movement as a streak in the image. At high image scales, the asteroid drifts in position over the length of the exposure and its star-like dot draws a line on the image. However, at low to medium image scales, the movement is imperceptible and no such drifting is recorded. For Mars and Vesta this month, the movement we're interested in recording and presenting occurs over days rather than the length of a typical long exposure photograph, and this requires a different strategy.

The best way to show movement over several nights is to create a composite image. Combining results from each night, a single image can be created which shows the apparent movement of an object.

Although at first this seems like a straightforward task, there are caveats. The weather can play havoc with this type of image presentation, creating unwanted gaps and, where it's poor, destroying the impression of movement. The Moon changes the brightness of the surrounding sky, which can also create issues with the composite.

In the background

One of the biggest considerations is positional reference. If you're lucky enough to have an observatory in which you can leave a telescope plus camera setup untouched for the sequence duration, then fine. But if, like most imagers, you need to move things between shots, getting the final images registered to one another can be a challenge. Fortunately, the stars come to the rescue, as they create an effectively fixed background reference.

Even here there are potential issues; if the sky conditions vary from night to night, it's important that the positions of the reference stars are recorded.

Then there's the issue of twilight shooting, when there may be no stars seen at all. Here, you rely on the foreground horizon for reference, ensuring that each shot is made at the same time from one night to the next. Time this incorrectly for an evening shoot and you may get close to sunset, naturally bringing the sequence to an unwanted and abrupt end.

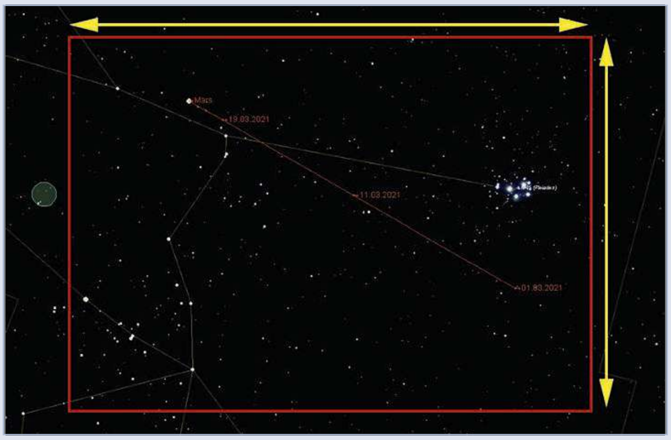
In the step-by-step instructions opposite you'll find some more tips for creating a motion composite. See whether you can record the motion of Mars through Taurus this month, along with the more sedate movement of Vesta at opposition in Leo.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Recommended equipment: DSLR, lens as determined by field size, tripod, remote shutter release cable

Send your images to: gallery@skyatnightmagazine.com

Step by step



STEP 1

Using a Planetarium program (eg **stellarium.org**) work out the capture field of view for the desired date range. A field calculator can determine the setup to achieve this (see **skyatnightmagazine.com/astronomy-field-view-calculator**). Work out the centre of the field of view and frame orientation in terms of background stars.

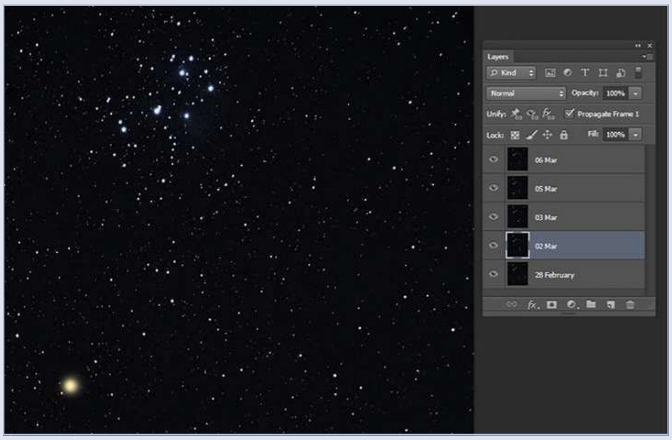
STEP 2

With your gear set up and pointed at the centre of the field of view, take a test shot. For non-tracked shots with, say, a camera on a fixed tripod use the '500 Rule' (left) to determine the longest exposure you can take without star trailing.

If you divide 500 by the attached lens/telescope focal length (mm), this gives you the maximum exposure in seconds.

STEP 3

Set your ISO to a lowish value (eg ISO 400–1600). If using a camera lens, set the f/-number low and then increase it by a stop or two to reduce potential image distortion at the frame's edge. Use an exposure setting lower than the maximum in Step 2 and take a test shot. Examine for background stars – more than three is ideal.

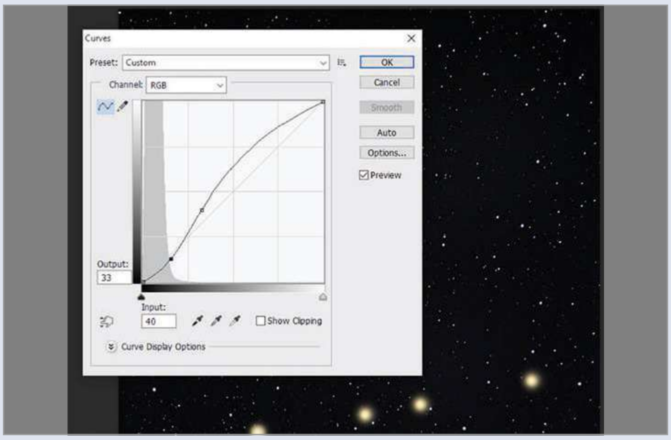


STEP 4

Take your photo and record setup and settings details, then repeat over several nights. Use the first image as a reference, tweaking settings to achieve a similar number of background stars. Next, load all the shots in date order into a layer-based editor, each as a separate layer, oldest at the bottom.

STEP 5

Make all but the lowest layer hidden. Turn visibility on for next layer up and transparency to 50%; adjust its position so the stars align accurately. Set its transparency to 0% and hide. Repeat for all layers using the lowest as the reference. Next, make all layers visible and set the blend mode for all except the lowest to lighten.



STEP 6

The background sky of the lowest layer should be bright enough to dominate. If it's poor, you can swap with a better one but set the lowest layer's blend mode to 'normal', all upper layers to 'lighten'. If upper backgrounds 'shine' through, dim them with the curves tool, applying an S-shape curve adjustment over the histogram.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

APY Masterclass

Catch a star of many colours

Use a defocus technique and stacking software to reveal details

Astronomy Photographer of the Year

Advice from a highly commended entrant in the 'Stars and Nebulae' category

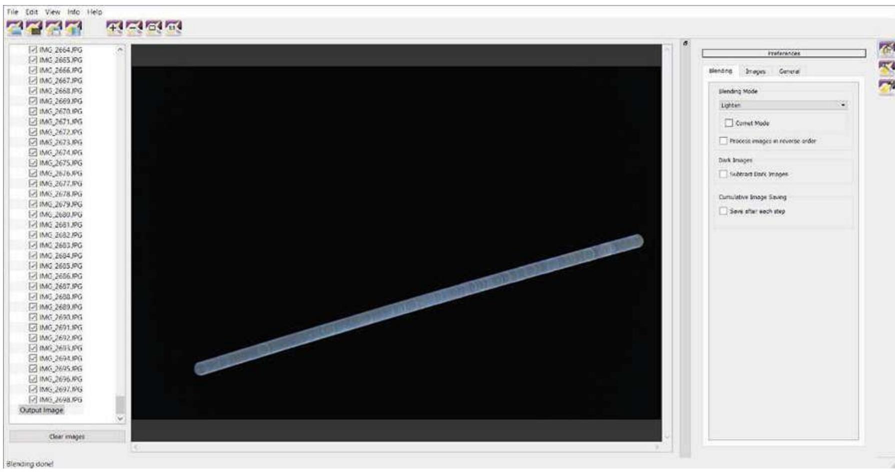
One of the highlights of the winter stargazing season is the bright star Sirius. Shining at mag. –1.46, it's the brightest star in the night sky. Often noticeable when close to the horizon, Sirius displays myriad colours as its light travels through our turbulent atmosphere. The sight of twinkling Sirius demands attention and even a few seconds of observing will reveal a rainbow of colours. We're going to look at one of the easiest ways to capture these colours in an image, by using a simple defocus technique and a free stacking software, in this case StarStaX.

To capture the colours of Sirius you'll need a DSLR or mirrorless camera with a zoom lens of at least 150mm, with 200mm–400mm being ideal. In our example, we used a 250mm lens set to the maximum 250mm focal length. This type of shot does not require tracking, so a basic tripod will be fine. Choosing an evening when the air is turbulent will also help to bring out the range of colours displayed by Sirius; ironically this is one of the few times that most of us wouldn't usually do any observing or imaging.

Capturing colours

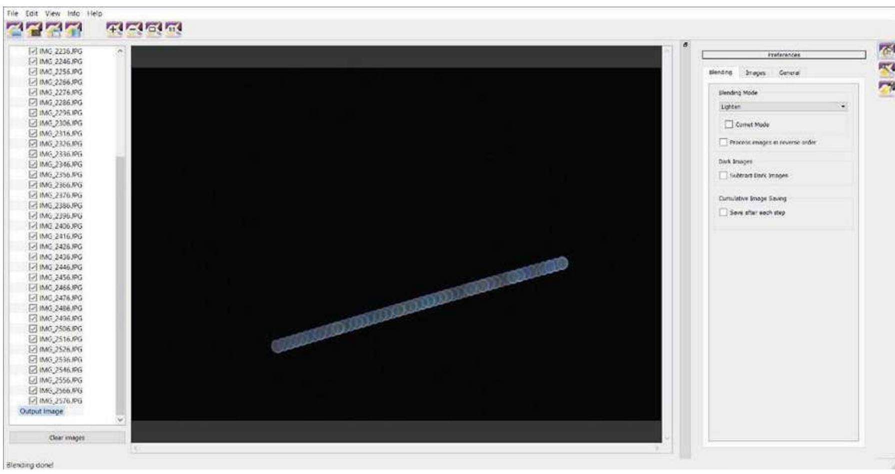
Start by selecting the manual or 'bulb' setting on your camera and centre Sirius in the viewfinder. Normally, for astrophotography we would be aiming for perfect focus, but for this type of shot we need the star to be slightly out of focus to bring out the colours. While viewing Sirius in the viewfinder or on the display screen, set the lens focus to manual and turn the focus ring so that the star appears as a disc. You should be aiming for Sirius to be captured as a large and bright circle that displays some obvious colours of its twinkling. Start with the lowest f/-stop that your lens will go to (eg f/2.8) and then take a picture with a one-second exposure at ISO 200. If the resulting image is too dark then increase the exposure slightly. Remember that an exposure that's too long will result in a white image, so this shouldn't be increased too much. Take a series of test images until you are happy.

The next stage is to capture a series of images that you can subsequently stack together to create a final composition. Move the camera up and to the right so that Sirius stays in view but is located towards the bottom left of the frame. With time, the star will move up and to the right of the frame. Using the

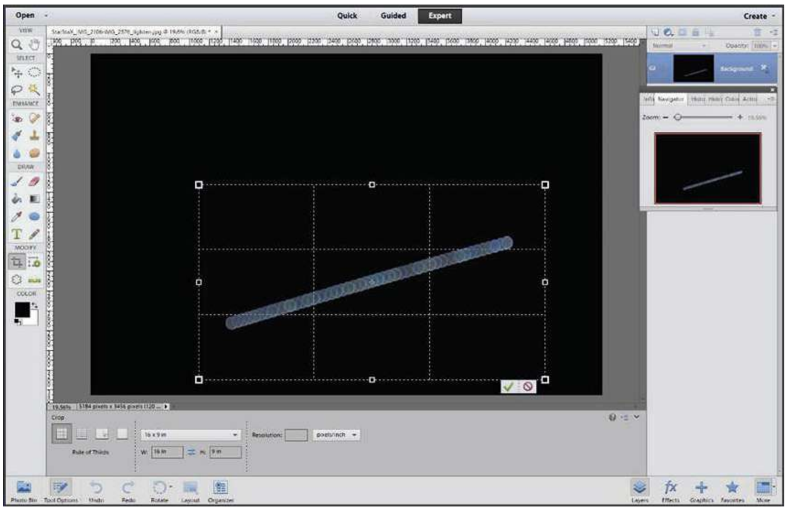


▲ Screenshot 1: the initial stack of Sirius images in StarStaX

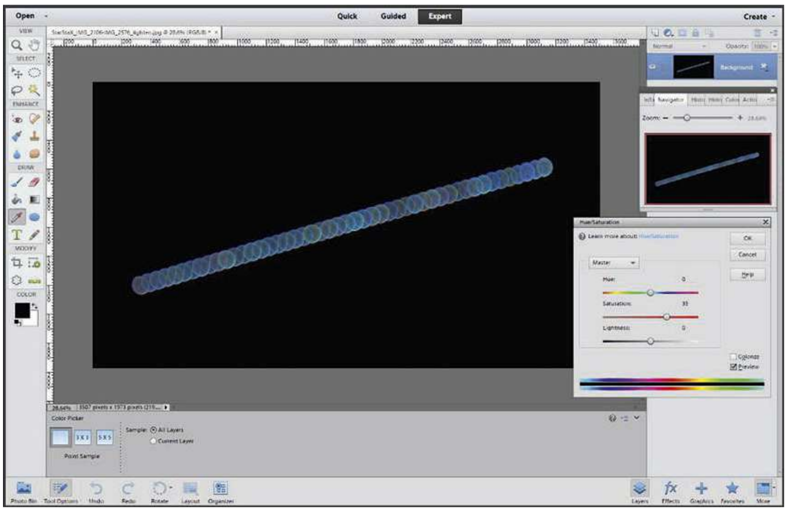
▼ Screenshot 2: using a selection of one in ten stacked images in StarStaX



ALL PICTURES: STEVE BROWN



▲ Screenshot 3: using Photoshop to crop the stacked images



▲ **Screenshot 4: adjustments can be made to the colour saturation of the stacked images in Photoshop**

camera's internal intervalometer or a remote shutter release cable, set the camera to take a continuous series of pictures to capture this. In our example, this took about 20 minutes and resulted in 720 pictures.

Download the images and then drag and drop them into the left-hand window of the StarStaX software. Next, click the 'Start Processing' icon from the options at the top left. The software features various stacking options, but the default settings are fine for our image. The software will run, stacking all the images in turn and the result will initially be a poorly defined streak of colour (see Screenshot 1). To make the result more aesthetically pleasing you can repeat the process using fewer images. There are two options; you can either clear the images and then drag and drop a selected range, say one in ten (see Screenshot 2) and stack again, or untick the images you don't want from the list in StarStaX and repeat the stacking process. Try out different combinations until you're happy.

In Photoshop, crop the image so there is an even amount of black space around the stacked frames (see Screenshot 3). You can also increase the 'Saturation' a bit with the 'Hue/ Saturation' settings to enhance the colours (see Screenshot 4).

Our final picture (below) used a range of images from the middle of the original set and then one in ten of those were chosen for the final composite. It gives the impression of a series of captured Sirius twinkles as it moves through the night sky.

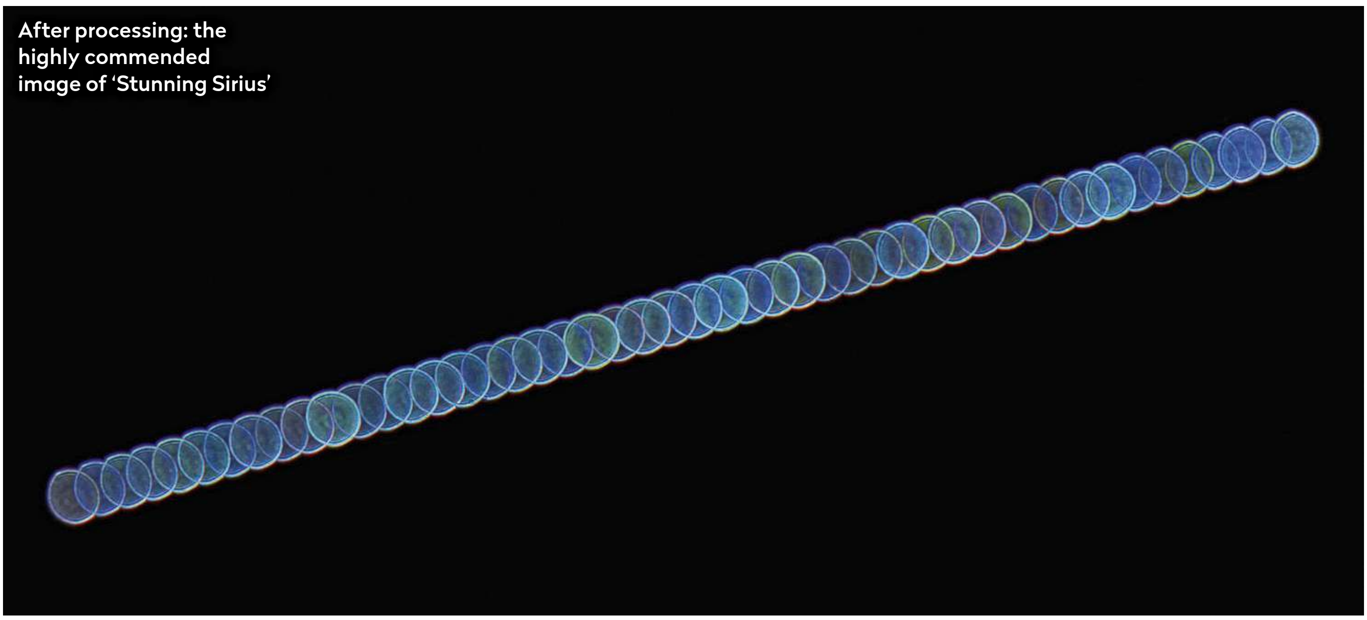
Steve Brown is a North Yorkshire-based astrophotographer who was highly commended in the IIAPY 2020 'Stars and Nebulae' category with 'Stunning Sirius'

3 QUICK TIPS

1. Resist the urge to check the progress of your captures as you may wobble the camera between shots.

2. Switch on the camera's 'noise reduction', to automatically remove dust shadows and hot pixels from each frame.

3. Don't use images from the extreme edge of the frame, as these may not be circular due to lens distortion.



After processing: the highly commended image of 'Stunning Sirius'

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

PHOTO OF THE MONTH

◁ The Horsehead Nebula

Terry Hancock, Colorado, USA, 26–29 September and 24–26 November 2020

Terry says: "The Horsehead Nebula is one of the most beautiful objects in the night sky. In this Hubble Palette version, created with narrowband filters, the Sulphur (SII) wavelength is mapped to the red channel, the Hydrogen-alpha (Ha) is mapped to green and the Oxygen (OIII) is mapped to blue. While the colours aren't the true colours, the narrowband filters reveal more of the hidden gasses not seen in a visible light image."

Equipment: QHY600 mono camera, Takahashi FSQ-130 apo refractor, Paramount ME mount **Exposure:** 27.1h total **Software:** MaxIm DL, PixInsight, Photoshop

Terry's top tips: "I'm fortunate to have high-end equipment, but stunning photos of the Horsehead Nebula can still be obtained with a modest and less costly setup. I recommend using either a late model DSLR or a dedicated one-shot colour CMOS camera. Dual bandwidth filters (reasonably priced and made specifically for one-shot colour cameras) are perfect if you live in a light-polluted area or want to capture more of the huge glowing cloud of hydrogen gas behind the Horsehead. Using this type of filter will also help to keep bright stars such as Alnitak under control and minimise its sometimes massive halo."

◁ Moon

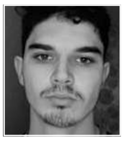
Damian Martin, Coalville, Leicestershire, 29 December 2020

Damian says: "This was my first attempt at imaging a full Moon. Due to the limited field of view, it's actually a composite of four separate images."

Equipment: Altair GPCAM3 178C camera, Meade LX85 8-inch ACF and mount **Exposure:** 4 x 2" **Software:** PIPP, AutoStakkert!, MICE, RegiStax

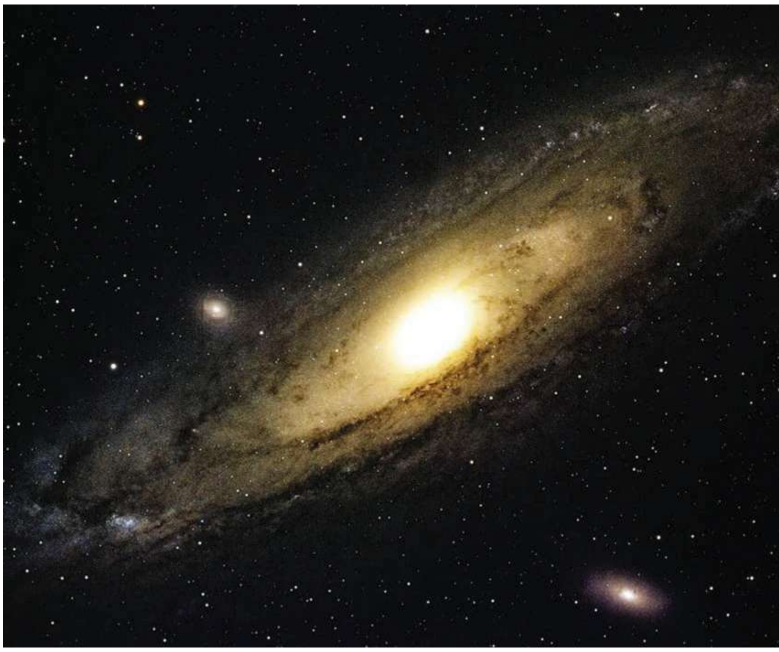
The Andromeda Galaxy ▷

Niall Donovan, Manchester, 24 September 2020



Niall says: "I live near Manchester's centre where the light pollution is terrible, so I had to use a filter to capture this image."

Equipment: Atik 16200 mono camera, Celestron NexStar 8SE **Exposure:** 7h total **Software:** Astroart, Photoshop

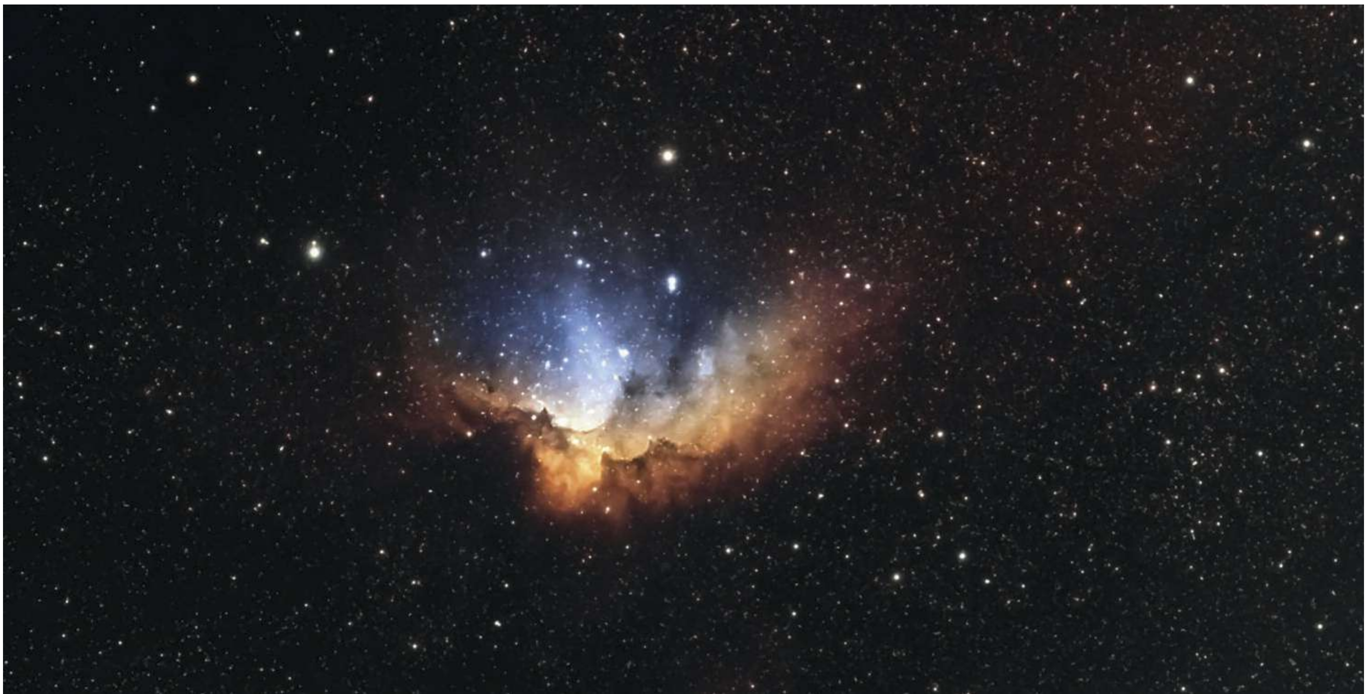


▽ The Wizard Nebula, NGC 7380

Rachael & Jonathan Wood, Doncaster, 30 July & 19 August 2020

Rachael says: "We've been astro imaging since August 2019. Here is a capture of the Wizard Nebula, which was taken from our back garden."

Equipment: ZWO ASI 294MC Pro camera, Sky-Watcher Evostar ED80 refractor, Sky-Watcher HEQ5 Pro mount **Exposure:** 4h total **Software:** Astro Pixel Processor, Photoshop



◁ The gas giants setting

Dave Frost, Matlock, Derbyshire, 20 December 2020

Dave says: "The Great Conjunction on the 21 December was going to be cloudy, so I decided to make the best of the evening before, and took a shot every four minutes while the two gas giants set."

Equipment: Canon M5 mirrorless camera, Canon 100mm f/2.8 lens, Manfrotto tripod **Exposure:** ISO 100 f/2.8, 1/100" **Software:** Photoshop

◁ The Whirlpool Galaxy, M51

Andy McGregor, Inverarnie, Inverness, April 2020

Andy says: "This is my first target with guiding and it's the first time I'd used PixInsight; it's a huge step up from the blurry photos I was taking just a year ago."

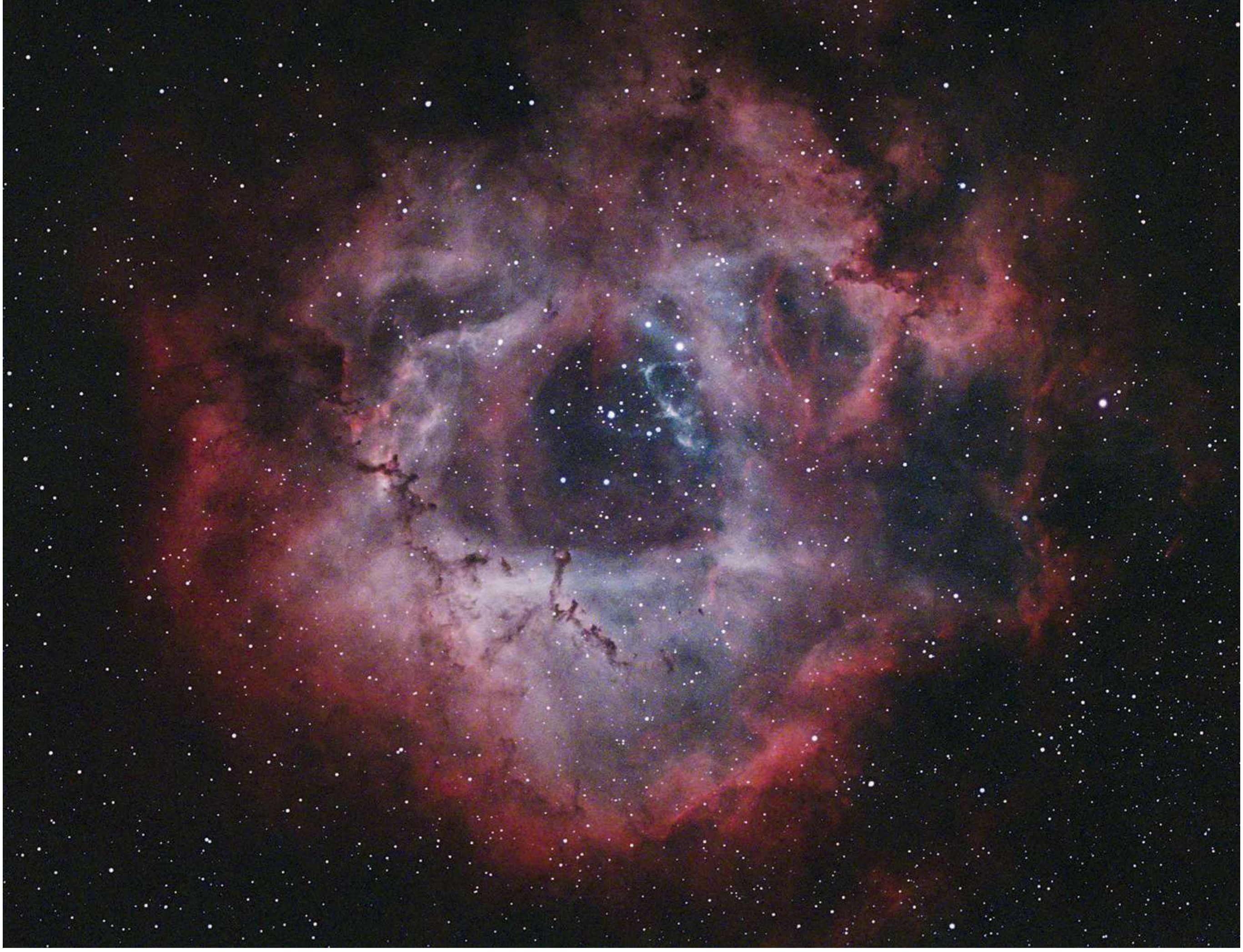
Equipment: Fuji X-T3 mirrorless camera, William Optics Zenithstar 103 apo refractor, Sky-Watcher HEQ5 mount **Exposure:** ISO 1600, 55x 240", 10x 480" **Software:** Astro Pixel Processor, PixInsight, Photoshop, Topaz DeNoise

The Pleiades, M45 ▷

Mike Read, Corsley, Wiltshire, 13 December 2020

Mike says: "The Pleiades is a cluster I've always wanted to capture. When I saw the first sub exposure, I was elated that I managed to capture the dust lanes so well."

Equipment: ZWO ASI 533MC camera, Sky-Watcher Esprit 100ED apo triplet refractor, Sky-Watcher EQ6-R mount **Exposure:** 22x 300" **Software:** NINA, PHD2, PixInsight



△ The Rosette Nebula

Martin Bracken, Chelmsford, 27 December 2020

Martin says: "I was amazed to see the detail I could achieve with a new Optolong L-eXtreme filter and a new scope. It's a steep learning curve, but enhanced technology really does bring the opportunity for capturing amazing images into the reach of everyone."

Equipment: ZWO ASI 294MC Pro colour camera, Sky-Watcher Esprit 100ED apo triplet refractor, Sky-Watcher HEQ5 Pro mount **Exposure:** 20x 360" **Software:** APT, PixInsight, Photoshop

Conjunction of Jupiter and Saturn ▷

Jeffrey O Johnson, Las Cruces, New Mexico, USA, 20 December 2020

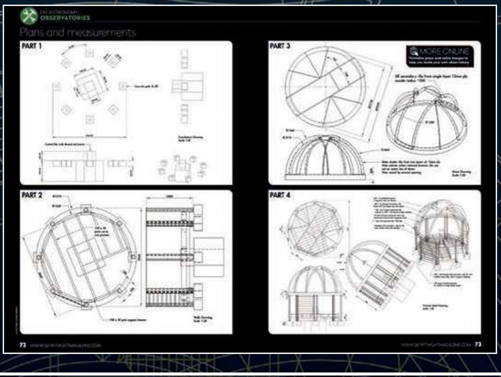
Jeffrey says: "I took some test shots of the Moon (while the sky was still blue), then moved to the two planets, taking many different frames at different settings before stacking the eight best."

Equipment: Canon T3i DSLR, Takahashi TOA-130NFB triplet refractor, Takahashi EM200 mount **Exposure:** ISO 100, 1/25" **Software:** RegiStax

ENTER TO WIN A PRIZE. HERE'S HOW:

Whether you're a seasoned astro-photographer or a beginner, we'd love to see your images. Email them to contactus@skyatnightmagazine.com. Ts&Cs: www.immediate.co.uk/terms-and-conditions

SPECIAL EDITION



ONLY £9.99 INC P&P*

FROM THE MAKERS OF BBC **Sky at Night** MAGAZINE

THE BIG BOOK OF DIY ASTRONOMY PROJECTS

Discover how to make a mount for comfortably observing the stars with binoculars, a smartphone holder for afocal imaging and even your own telescopes with *The Big Book of DIY Astronomy Projects*. In this special edition, the experts from *BBC Sky at Night Magazine* show you how you can make your own equipment using everyday objects. With 33 projects covering accessories, telescopes, solar observing, mounts, observatories and imaging, this fully illustrated special edition features clear instructions, step-by-step guides and detailed illustrations and plans – all to help you see the stars without breaking the bank.

Plus – subscribers to *BBC Sky at Night Magazine* receive FREE UK delivery on this special edition.

ORDER YOUR COPY TODAY

www.buysubscriptions.com/astronomymakes

Alternatively call 03330 162138† and quote 'ASTRONOMY MAKES PRINT1'

†Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open Monday to Friday 9am–5pm for orders only.
*Subscribers to *BBC Sky at Night Magazine* receive FREE UK POSTAGE on this special edition. Prices including postage are: £11.49 for all non-subscribers, £12.99 for Europe and £13.49 for the Rest of World.
All orders subject to availability. Please allow up to 21 days for delivery.

SUBSCRIBE

Discover the best new kit each month

The best in equipment, accessories and books each month

REVIEWS

Find out more about how we test equipment at
www.skyatnightmagazine.com/scoring-categories

90

Sky-Watcher's latest Star Adventurer tracking mount, the 2i, comes with built-in Wi-Fi. We put it to the test.

PLUS: Books on commercial space flight and the history of the Universe in 100 stars, plus a roundup of must-have gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding
★★★★★ Very good
★★★★★ Good
★★★★★ Average
★★★★★ Poor/avoid

@THESHED/PHOTOSTUDIO

Our experts review the latest kit

FIRST LIGHT

Altair Hypercam 26C APS-C colour 16-bit camera

A highly capable camera that excels at deep-sky astrophotography

WORDS: TIM JARDINE

VITAL STATS

- **Price** £1,799
- **Size** 108mm x 85mm diameter
- **Sensor** Sony IMX571
- **Resolution** 26MP, 6,224 x 4,168 pixels
- **DDR memory** 512MB
- **Exposure range** 0.1 ms – 3,600 seconds
- **Power** 12V DC (supplied)
- **Weight** 0.6kg
- **Supplier** Altair Astro
- **Tel** 01263 731505
- **www.** altairastro.com

Altair Astro has entered the emerging 16-bit astronomy camera market with its new Hypercam 26C colour camera. A significant upgrade over previous models, it has a large APS-C-sized sensor with 512MB of built-in DDR memory and produces full colour 26MB images.

Although the Hypercam 26C features a CMOS sensor designed for DSLR cameras, it retains a reasonably slender, circular design and is surprisingly lightweight. We fitted the camera to our filter wheel via the standard M42 thread on the camera's front. There's no need for infrared and ultraviolet blocking filters, though, thanks to the optical window in front of the CMOS sensor that blocks these wavelengths. But if you use a light pollution filter or one of the newer duo, tri, or quad bandwidth filters, you'll need a 2-inch version to cover the sensor.

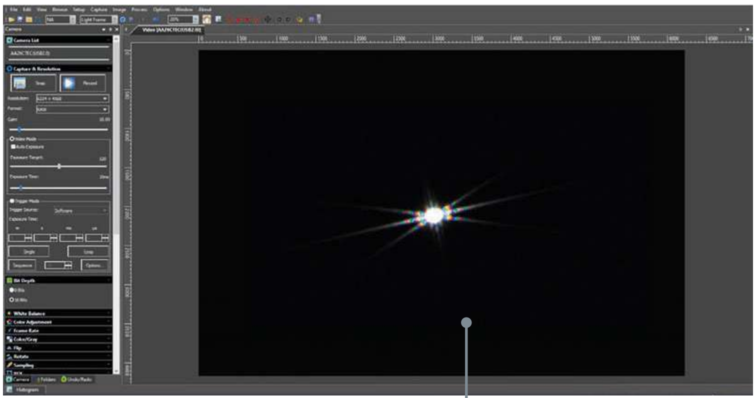
There was no software supplied in the box with the camera, but a simple download from the Altair Astro website (**altairastro.com**) installed the camera drivers along with image-capture software. We also downloaded the ASCOM driver for the camera (ASCOM being the industry-standard interface that allows different pieces of astronomical equipment to communicate) so that we could use it with our preferred observatory program. Although the ASCOM driver allowed basic use of the camera it was a bit clunky and some features were unavailable, most notably the controls for the heated optical window, so at times we reverted to the supplied software for captures. Our observatory uses USB 2.0 hubs; these ran the camera perfectly, but data transfer is more efficient in USB 3.0 mode and frame rates are improved, so it would have been good to see that as an option on the camera.

Added benefits

After allowing a few minutes for the cooling system to stabilise we chose a familiar target, the Pleiades, M45, to take some test images and to get a feel for the exposure settings to use on the camera. From the outset it became clear that this 16-bit camera is very different to the 12-bit models we have reviewed previously; with a wide range of available configurations governing exposure length and gain settings, we felt it would take us quite a number of clear nights experimenting to determine the optimal settings for each target. With a set time limit for the review we decided to use just three arbitrary gain settings to ensure we got a selection of useable photographs, but we think the camera is likely to be capable of much better results than we achieved during our time with it, which was hindered in part ▸

Detailed sensor

With 6,224 x 4,168 pixels, the Sony CMOS sensor in the Hypercam 26C APS-C offers plenty of imaging real estate, with 28.3mm across the diagonal, making it ideally suited to telescopes offering a larger, coma-free image circle. Aside from an increased image area to work with, what sets the IMX571 sensor apart from the majority of astro cameras is its true 16-bit capability. This allows the camera to capture over 65,000 levels of intensity within an image, making it ideally suited for astrophotography, where – unlike standard daytime photography – we are looking to extract the faintest hidden details and the brightest of stars from within the captured data. Noise (unwanted artefacts) is kept to a minimum in the back-lit Sony sensor, allowing higher gain settings to be used for speedier image acquisition, without compromising on image quality. With a given peak Qe (Quantum efficiency) of 80 per cent, the 26C easily collects data from the faintest objects, revealing hidden galaxies and delicate nebulosity within images.



Capture software

Altair supplies a dedicated imaging program, AltairCapture, to use with the Hypercam 26C, which is downloadable from **altairastro.com**. This allows you to control every aspect of the camera, and easily adjust gain, bit depth, exposure length, cooling and heating options, region of interest imaging, plus many more aspects including live focusing routines.

Heated optical window

In front of the CMOS sensor there is an optical window for blocking infrared and ultraviolet light. In certain damp conditions cooled cameras can suffer from dew spots that form on the window, which are difficult to remove and can spoil the images. The Hypercam is equipped with a controllable heating element which alleviates this issue.

Thermo Electric Cooling (TEC) system

Camera sensors produce heat, especially during long exposures, which can result in noise (unwanted artefacts) in images. The Hypercam 26C is capable of cooling the camera to 35°C below ambient temperature. This allows the user to set a working temperature that is achievable all year round, which is ideal for taking a matching dark frame library.

USB 2.0 hub

Multiple tangled cables are a nightmare for astrophotographers. On the rear of the camera there are two USB 2.0 sockets, which can be used with light, short cables for low bandwidth accessories like filter wheels, to cut down on cable weight and clutter.

Armoured case

The camera is supplied with a sturdy black ABS (hard plastic) case that makes it safe to transport and store the camera. This includes foam inserts with cut-outs for the camera, power supply and cables. For added security, the design will accommodate dual padlocks.

KIT TO ADD

1. Altair 2-inch magnetic filter holder

2. Altair QuadBand 2-inch light pollution filter

3. Altair 70mm ED Triplet APO refractor telescope

▸ by cloud and wet weather.

That said, with some notable high-dynamic-range targets available in the sky – namely the Orion Nebula, M42, and the Andromeda Galaxy, M31 – it gave the camera a chance to demonstrate what it could do on a single target that has an extreme variance between its brightest and faintest areas. It was especially pleasing to see that the Trapezium Cluster within the Orion Nebula was captured in great detail without blowing out the individual stars, while in the same exposure the much fainter gas clouds and nebulosity were also revealed. We found the same was true for M31, with the bright core of the galaxy showing nice detail along with good structure in the dark dust lanes further from the core. We feel the results obtained from the camera demonstrate that it would allow our equipment to produce images representing the very best that the prevailing conditions could allow.

The Hypercam 26C is particularly well suited for long exposure deep-sky astrophotography. While it is possible to select a smaller region of interest to work with, the camera isn't ideal for planetary imaging, and in full-frame mode the captured file sizes really start to add up, with each individual RAW file taking up nearly 50MB of disk space. In turn this means that a reasonably decent specification computer is desirable for post-processing the large files you get from a stacked imaging run.

To sum up, we found that the Hypercam 26C offered top-quality full colour photographs at the upper limit of what our equipment and sky quality permitted. Indeed, it proved itself to be a highly capable camera.

VERDICT

Build & Design	★★★★½
Connectivity	★★★★★
Ease of use	★★★★
Features	★★★★½
Imaging quality	★★★★½
OVERALL	★★★★½

@THESHED/PHOTOSTUDIO, TIM JARDINE X 2

▲ The Andromeda Galaxy, taken with the Hypercam 26C paired with a Sky-Watcher Esprit 150ED telescope, using 5' exposures and 10% gain with 1 hour and 45 minutes of total integration

▼ M42, taken with the Hypercam 26C paired with a Sky-Watcher Esprit 150ED telescope, using 5' exposures and the lowest gain setting with 1 hour and 25 minutes of total integration

Sky-Watcher Star Adventurer 2i Pro Pack camera tracking mount

A highly portable tracking mount, which benefits from easy-to-use Wi-Fi control

WORDS: PAUL MONEY

VITAL STATS

- **Price** £349
- **Payload capacity** 5kg
- **Latitude adjustment** 0–90°
- **Tracking rates** Sidereal, Lunar and Solar, App, Timelapse (Astro, Regular and Long Exposures), Off
- **Power requirements** 4x AA batteries or 5V DC external supply
- **Polarscope** Polarscope with separate red-light illuminator
- **Extras** Dovetail 'L' mounting bracket, built-in Wi-Fi, camera 'Snap' control port, guide port, ¼-inch – ⅜-inch thread converter
- **Weight** 1kg
- **Supplier** Optical Vision Ltd
- **Tel** 01359 244200
- **www.** opticalvision.co.uk

Star tracking mounts that are light and portable – which are suitable for cameras and small telescopes – have become popular in recent years. One of these is Sky-Watcher's Star Adventurer tracking mount, which we reviewed in October 2014. The latest incarnation has just been released, the Star Adventurer 2i Wi-fi Pro Pack, and we took it for a test on the few clear nights we had at our disposal.

The Star Adventurer 2i looks fresh and new in its white livery, which helps to make it more visible at night than the original metallic red version. The design is faithful to the original model and the 'Pro pack' consists of the Wi-Fi-enabled mount, ball head adaptor, illuminated polarscope, dovetail L-bracket, equatorial wedge and counterweight shaft with a 1kg counterweight. Power is provided by four AA batteries or an external 5V DC power supply. If you intend to use the camera 'Snap' feature check the electronic shutter release cable required for your camera before you buy; the OVL website (**opticalvision.co.uk**) lists many camera makes with available cables.

For wide-field imaging with, say, 16mm through to ~100mm lenses, the ball head adaptor allows you to use a tripod ball head (sold separately) to attach the camera to the mount. You'll also need to purchase a separately sold tripod, which is recommended as this will provide a good solid support for your setup. For longer, heavier lenses or for small, short-focus scopes the dovetail L-bracket and counterweight is indispensable – Sky-Watcher recommends a maximum load of 5kg. For our review we used lenses that ranged from 18mm to 400mm with our Canon 50D and modified 300D DSLRs, and then swapped to our Equinox 80ED refractor with the same DSLRs.

Polar alignment

When you use the supplied round (and vivid green) Vixen-style mounting adaptor to attach the ball head and camera to the mount, you'll find that the adaptor covers the polar axis, which means that you'll have trouble with polar alignment as the view will be blocked. The way round this is to polar align first and then put the adaptor, ball head and camera on ▸

Wi-Fi control and app

By adding an in-built Wi-Fi adaptor, Sky-Watcher has brought the Star Adventurer into the 21st century. Many people are familiar with Wi-Fi control of gadgets and this is appealing to astrophotographers who enjoy using a lightweight and portable mount and controlling it with a smartphone. There are many options, but when the app is used in conjunction with the camera 'Snap' port, we found the control of our camera worked a treat. For example, exposure duration and groups of exposures can be set and stored for repeated use.

The app allows control and adjustment of the right ascension (RA) axis of the mount to help with fine tuning the target in the field of view, something we found useful when capturing the conjunction of Jupiter and Saturn. Another useful feature is the Polaris position chart, as this helps with the setting up process. There is also a 'Bulb' mode that requires you to hold the exposure 'button' down for as long as you want the exposure to continue.

@THESHED/PHOTOSTUDIO X 4, PAUL MONEY X 2

SCALE

Switches and guide port

On one side is the main selector knob which allows you to choose from 'Sidereal', 'Lunar' and 'Solar' tracking rates, 'App' and 'Off' options, as well as settings for time-lapse photography. On the other side you'll find left and right arrow buttons, a 'S/N' (South/North) selection switch, the camera 'Snap' port, the 'Auto Guider' port and a socket for an external 5V power supply.

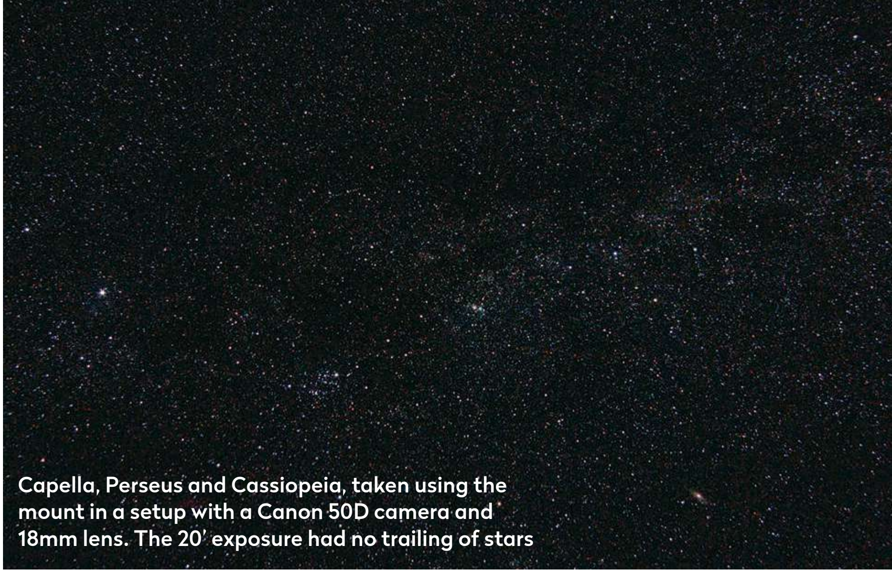
Tracking mount body

The mount body is the workhorse of the Star Adventurer 2i. It contains the integrated polarscope, control selection knob and various ports, yet is quite lightweight and can be used when it's attached directly to a tripod – with latitude adjustment done via the tripod's tilt head – or with the supplied equatorial wedge.

Equatorial wedge

The equatorial wedge can be set from zero to 90° latitude for either Southern or Northern Hemispheres with an easy to use adjustment knob and locking handle. We found that longitude adjustment via two adjustable bolts helped to fine-tune the alignment; the bubble level also helped to level the mount.

CAMERAS FOR ILLUSTRATIONAL PURPOSES ONLY


Capella, Perseus and Cassiopeia, taken using the mount in a setup with a Canon 50D camera and 18mm lens. The 20' exposure had no trailing of stars


Jupiter and Saturn on 20 December, taken with a ZWO ASI 224 colour camera and an Equinox 80ED refractor


Orion's Sword and Belt – taken with a Canon 300D modified DSLR with a 100mm lens

KIT TO ADD

1. Star Adventurer tripod

2. Fotomate H-26QR tripod ball head

3. Sky-Watcher shutter release cable (camera model required)

▸ afterwards ready for imaging. If you are using the dovetail L-bracket and counterweight, then there is a slot allowing you to polar align with all the equipment still attached, which is handy as the extra weight could slightly alter your polar alignment.

Control options

Rotating the control knob, you can select a range of presets, which include the usual 'Lunar', 'Solar' or 'Sidereal' options, but there is now an interesting 'App' addition. This is the setting to use when you're controlling the mount via the Wi-Fi and the free Star Adventurer Console app for Android and iOS platforms. We found the app had lots of functions and was very easy to use; its primary function is to set the tracking rate and length, and number of exposures, all of which can be stored, which is handy for repeated use.

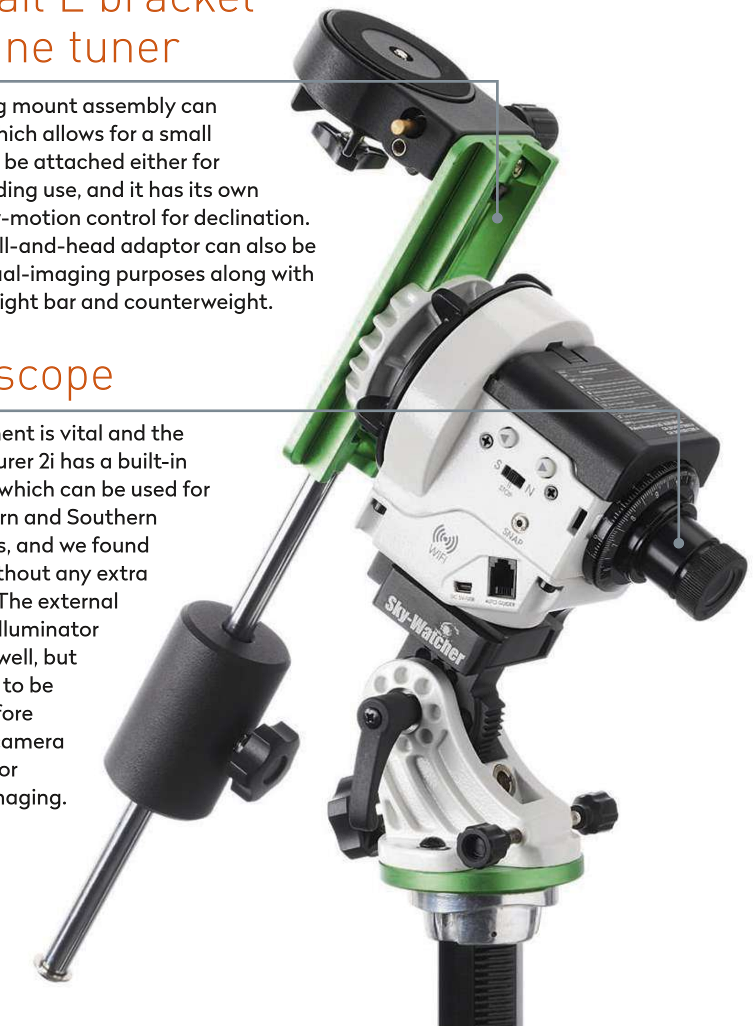
Once polar-aligned, we programmed a range of timings using the app with the Canon 50D and its 18–55mm lens set at 18mm. We took a 30-minute exposure of the constellations of Cassiopeia down to Perseus with only slight star trailing. Although light pollution and a slightly hazy atmosphere did not help, a 20-minute exposure revealed pin sharp stars.

Satisfied that the mount functions well with a wide-field lens, we replaced the ball head with the dovetail L-bracket and counterweight to try it with our 100–400mm lens. With the lens set at 100mm we observed Orion's heart and achieved five-minute exposures with no trailing. Next, we set it at 400mm and tried the Pleiades, achieving two-minute exposures. We stacked nine of the Pleiades exposures for an image and if conditions had allowed, we would have been able to leave it running for more with a great result. Finally, on the night before Jupiter and Saturn's Great Conjunction we tested the mount and our Equinox 80ED refractor, using both a DSLR and ASI 224 colour camera, to capture the close encounter.

Overall, the addition of Wi-Fi to the Star Adventurer 2i Pro Pack gives a new string to its bow and makes it a stunning piece of kit for any astrophotographer.

VERDICT

Assembly	★★★★★
Build & design	★★★★½
Ease of use	★★★★½
Features	★★★★½
Tracking accuracy	★★★★½
OVERALL	★★★★½



Dovetail L-bracket with fine tuner

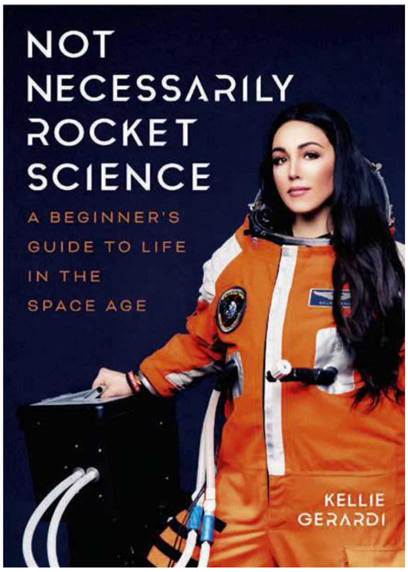
A fine-tuning mount assembly can be added, which allows for a small telescope to be attached either for visual or guiding use, and it has its own manual slow-motion control for declination. A second ball-and-head adaptor can also be added for dual-imaging purposes along with a counterweight bar and counterweight.

Polarscope

Polar alignment is vital and the Star Adventurer 2i has a built-in polarscope, which can be used for both Northern and Southern Hemispheres, and we found it worked without any extra calibration. The external polarscope illuminator does its job well, but it does need to be removed before adding the camera equipment for wide-field imaging.

New astronomy and space titles reviewed

BOOKS



Not Necessarily Rocket Science

Kellie Gerardi
Mango Publishing
£18.95 ● HB

Kellie Gerardi, a science communicator working in the spaceflight industry, promises us "a complete guide to the space age", starting at the very beginning of the Universe and working through her attempts to break into the space industry with a non-STEM degree, her involvement with Mars One and her work with rockets in the Mojave Desert.

It's a lofty aim, and the result is part memoir, part self-help, part history of the Universe and spaceflight. Tips are given on how to get a career in a STEM (science, technology, engineering and maths) field and how to become an 'influencer'. However, a brief to be all-encompassing carries with it the risk of stretching the material thinly, and it is sometimes challenging to identify a cohesive thread to this book.

It does give a rare, personal insight into the business of commercial spaceflight, however. Gerardi also makes the point that we rarely hear about jobs in STEM outside academia and engineering. "There's no one specific background or degree required to contribute to space exploration" doesn't get said often enough, and she deserves credit for that.

But it's never quite explained how Gerardi got from science communications to working with rockets in the Mojave Desert, or what her job title was, so it is not a 'candid guide' as the blurb claims.

The book falls short of other objectives outlined on the front and back cover text too. It doesn't provide much in the way of practical advice telling the reader how to get on that alternative path to the spaceflight industry. Tips include "design your ideal reputation" and "there is no job too small". To become an influencer, "invest" and "carve out time". Another piece of advice: "turn up at the Goddard Memorial Dinner ('space prom')."

▲ Getting noticed: the Goddard Memorial Dinner is recommended as a place to make industry contacts

MILLER ENGINEERING AND RESEARCH CORPORATION

I also found the timeline jumps about, making the narrative tricky to follow and the text was often repetitive. While the book may appeal less to those seeking more academic or scientific advice, Gerardi's tips will be a useful entry point for readers with an interest in science communication on social media and other careers in the field, from creative writing to space fashion. ★★☆☆☆

***Katie Sawers** is a student of physics and astronomy at the University of Glasgow*

Interview with the author
Kellie Gerardi

Will space tourism for ordinary people happen in our lifetime?

I think so. Right now the price is high, and as competitors are drawn into the field I think it will become more accessible. It will be a luxury for the next few decades, but hopefully a more accessible luxury like how first-class flights are for a special occasion. Fewer than 700 humans have been to space, and the fact that Virgin Galactic could more than double that number in its first few years of operation is amazing.

What are your thoughts on the Commercial Crew Program?

It's incredible how far we've come in the last decade. NASA has been such a proactive partner in enabling this ecosystem to grow; it's an amazing thing to accomplish for SpaceX and Boeing. It's extraordinary that SpaceX has achieved what previously only nation states have. One of my buzzword phrases is the 'democratisation of access to space', and this is what that looks like.

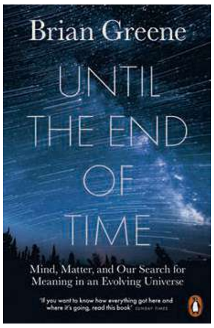
How do you feel about crewed missions to the Moon and Mars?

We need to invest in capabilities to sustain an off-Earth presence, and the Moon is a great candidate both in proximity and also as a soundbox for further destinations. I understand where people are coming from when they lament how we haven't been back out of low-Earth orbit since Apollo. We continue to do incredible things robotically, much further out, but I do think Mars is calling. I'm location agnostic when it comes to settlement on the Moon. If that's where we're going, I'll take it, and I'm very excited.

***Kellie Gerardi** is a commercial spaceflight industry professional and suborbital scientist*

Until The End Of Time

Brian Greene
Penguin Books
£10.99 ● PB



Perhaps one of the biggest mysteries in the Universe is why we are capable of understanding it. Where does the ability to do science come from and how is it linked to our species' evolution? Brian Greene, theoretical cosmologist and popular science writer (probably best known for *The Elegant Universe*) gets to grips with the biggest subject possible: the origin and potential fate of the Universe. He makes this ambitious task doubly so by including an account of our search for meaning in scientific data: a search characterised as a human affinity for telling stories, whether they are scientific ones about the facts we discover, or non-scientific narratives characterised as 'religion' and 'art'.

The chapters that start and conclude the book discuss the all-important concept of entropy and explain how ordered systems, such as life itself, can emerge from a Universe governed by the second law of thermodynamics and the overall slide towards disorder. The middle chapters examine the roles of art, culture and religion in human evolution but this discussion feels too brief to do justice to the subject matter. He also takes on consciousness, and here his dismissal of our apparent free will in a Universe ruled by physical laws feels one-sided.

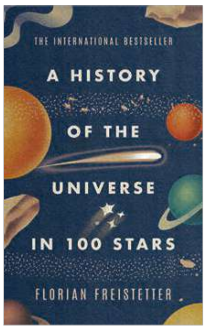
Greene's undoubted talent for science communication is demonstrated in his clear explanations of complex physics, but overall the book is an odd mixture of factual science and platitudes on the ability of art to uplift. ★★★☆☆

***Pippa Goldschmidt** is an astronomy and science writer*

A History of the Universe in 100 Stars

Florian Freistetter
Quercus
£16.99 ● HB

PACKED WITH FACTS



With 100 billion stars in the Milky Way (and over a billion trillion in the observable Universe), how do you choose just 100 to represent the entire astronomical bestiary? Well, that is just what the author of this delightful book has done.

The result – a superb translation from the original German – is convincing. In a series of three-page vignettes, the author visits almost every conceivable type of celestial object known to modern science, from tiny underground sparks of neutrino energy to enigmatic dark energy blobs and hypothetical Planck stars. Along the way we encounter much of the necessary scientific background, all covered in an accessible and patient manner.

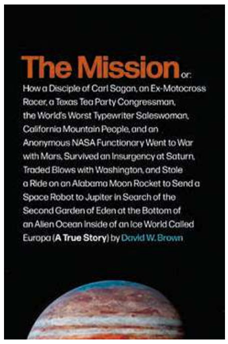
Some objects discussed are merely the starting points for historical developments rather than being interesting in their own right. But this doesn't make those brief sketches any less relevant or intriguing. Some objects aren't specific stars at all, but classes of stars, and some aren't even stars. But we can forgive the author the judicious use of the noun in the book title; the volume could hardly be called 'A History of the Universe in 100 Objects, Processes and Phenomena'!

The only minor downside to this book is that some of the topics are repeated, simply because the background material is required at different points throughout. But this is only really a problem if you decide to finish the book in a single sitting. Overall, dipped into occasionally, as the author expects, this is an excellent diversion for people of all levels of astronomical knowledge. ★★★★★

***Dr Alastair Gunn** is a radio astronomer at Jodrell Bank Observatory in Cheshire*

The Mission

David W Brown
Custom House
£25 ● HB



Written in a smooth, fluid style that offers a tip of the hat to Tom Wolfe's *The Right Stuff*, this beautiful book is a gem of an introduction to our Solar System and how, over decades, human minds and robotic spacecraft have learned more about it. The book particularly emphasises our decades-in-the-making desire and drive to visit Jupiter's ocean-bearing moon Europa, a potential candidate for past microbial life.

Freelance writer David W Brown, whose pen has seen service for *The New York Times* and *Scientific American*, introduces us to a knot of men and women from quite different backgrounds. His biographical sketches offer wit and humour in equal measure as we are guided through their respective careers which settled, often unexpectedly, upon the disciplines of astronomy, geology or planetary science.

Notably, we meet Robert Pappalardo, whose childhood trip to see a solar eclipse led him eventually to involvement in the Jupiter Icy Moons Orbiter, an Optimus Prime of a spacecraft that threatened to bankrupt NASA's space science budget. We meet ex-ring-binder saleswoman Louise Prockter, whose muddle through life – and having a combination of engineer/biology teacher parents – created a desire to explore worlds beyond her own. And we meet Ed Weiler, whose first task when put in charge of NASA's Mars Exploration Program was… to cancel the Mars Exploration Program and start with a clean sheet of paper.

Brown's prose is refreshing and demonstrates his credentials as a superb wordsmith, handling complex issues of science, technology and politics with stylistic flair. ★★★★★

***Ben Evans** is a science and astronomy writer and the author of several books on human spaceflight*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Syrp Genie One

Price £399 • **Supplier** Wex Photo Video
Tel 01603 486413 • **www.wexphotovideo.com**

ADVANCED Add a new dimension to star trail timelapses with the Syrp Genie One. The device helps with motion control, allowing you to slowly pan a camera to create a more dynamic end result. It connects to your laptop or phone via Bluetooth, Wi-Fi or USB-C and is controlled via an app.

2 Sky-Watcher 355mm Losmandy-style dovetail bar

Price £69.99 • **Supplier** Harrison Telescopes
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

With guidescopes, control computers, dew heaters and power supplies there can be lots to add to your optical tube, but this 355mm-dovetail bar can hold even the most complicated setups. Fits 75mm slots.

3 Midnight Astral Parker fountain pen

Price £65 • **Supplier** Cult Pens
Tel 01392 304866 • **www.cultpens.com**

The subtle design of silver constellations against a deep blue background makes this fountain pen a great way to show your love of the night sky. Presented in a gift box, it's supplied with a blue ink cartridge.

4 Orion dual beam Astro Lantern

Price £34.99 • **Supplier** Orion Telescopes
Tel 0800 041 8146 • **http://uk.telescope.com**

This rechargeable lantern comes with a bright white light to help with setting up and taking down observing equipment, while the red-light mode will maintain night vision. Magnetic clips make it simple to attach to your metal tripod or telescope barrel.

5 Far side of the Moon map tote bag

Price £14.99 • **Supplier** Present Indicative
Tel 01189 588586 • **www.presentindicative.com**

The lunar map that decorates this tote bag highlights the topography of an unfamiliar view of the Moon – its far side. Made from sturdy organic cotton, the 8cm depth means you can fill it with astronomy gear.

6 Nebulae boosting filter

Price £239 • **Supplier** The Widescreen Centre
Tel 01353 776199 • **www.widescreen-centre.co.uk**

Enhance your view of nebulae with this dual-band filter, which increases contrast by only letting through light from the hydrogen (H-alpha) and oxygen (OIII) within clouds. The filter can be used for visual observing, or with a one-shot colour or mono camera.

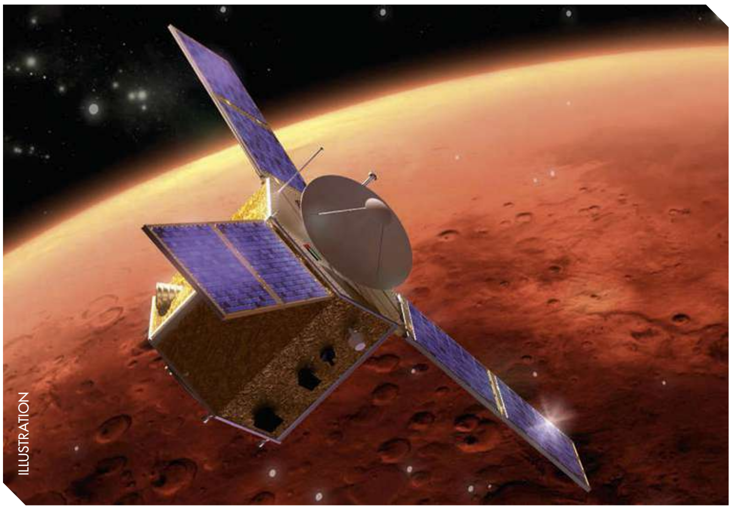

PULSAR
OBSERVATORIES
EUROPES LEADING OBSERVATORY DOMES
A Pulsar Observatory Dome is not just somewhere to store your equipment. It has many benefits that will allow you to take your home astronomy to the next level!
ADVANTAGES OF A PULSAR DOME:
- Observe in comfort
- Eliminates annoying stray light
- Protection from wind chill
- Less cooling down time
- Full automation potential
- Excellent dark adaption
- Virtually maintenance free
- Highest Quality GRP construction
- Simple home assembly
- Long life durability of GRP
- Installation service available
PRICES START FROM JUST £2595.00
Pulsar Observatories
Our Industry leading drive system makes full automation of your observatory dome easier than ever before!
CHECK OUT OUR WEBSITE FOR DRIVE OPTIONS AND DOME ACCESSORIES INCLUDING ANTI-VIBRATION PIERS AND PIER ADAPTER PLATES
www.pulsarobservatories.com
sales@pulsar-observatories.com
Tel: 01366 315006

Elizabeth Pearson interviews Hessa Al Matroushi

Q&A WITH A MARS SCIENTIST

With its first interplanetary spacecraft, Hope, due to arrive at Mars on 9 February, the United Arab Emirates embraces a new era of space travel

What is the UAE's Hope probe looking for at Mars?
The Emirates Mars Mission is looking into the different layers of the Red Planet's atmosphere. We're analysing the lower atmosphere to understand the climate and its different constituents, seeing how they vary on a daily and seasonal basis. We're also looking into the upper atmosphere – specifically the thermosphere, where we are examining carbon monoxide and oxygen, as well as the upper layer, the exosphere, where we are looking at hydrogen and oxygen. We are interested in finding out how these gases escape from the atmosphere and would like to understand if there is a connection between the layers and how the processes interact. For example, if there are changes in the lower atmosphere we'd like to know how this has an impact the upper atmosphere. Also, if there are events like dust storms we'd like to know how these processes work.



▲ First of many: the UAE space probe Hope's in-depth study of the Martian atmosphere is a first step in a space programme that aims to settle on the Red Planet

What science questions will the mission help answer?
Right now Mars is a barren land, but four billion years ago it may have looked like Earth; the Red Planet had a thick atmosphere and flowing water. An understanding of the changes on Mars over this time span can teach us valuable information about Earth itself, because we're all in the same Solar System.

A lot of probes have looked at Mars's atmosphere. What makes this one different?
One of the key things that the UAE wanted to do is to bring an innovative approach to the science community. Previous missions looked at the Martian atmosphere at specific times – for example at 2am and 2pm – meaning we don't have a comprehensive understanding of what happens in the atmosphere at every hour; there are missing links and information in there. Also, we might understand the atmosphere in a specific place on Mars, but we don't understand how it behaves globally. Hope will give us a comprehensive picture of the Martian atmosphere – daily, seasonally and over the whole year.

MOHAMMED BIN RASHID SPACE CENTRE

Hessa Al Matroushi is the science data and analysis lead for the Emirates Mars Mission

What instruments are on board?
There are three scientific instruments. First is the Emirates Exploration Imager (EXI), a 12-megapixel camera. EXI will give us colourful images of Mars, but it also has three ultraviolet bands that will give us information about water ice and ozone. Then we have the Emirates Mars Infrared Spectrometer (EMIRS), which will give us information about atmospheric temperature, surface temperature, dust distribution, water ice and water vapour in the Martian lower atmosphere. The third instrument is the Emirates Mars Ultraviolet Spectrometer (EMUS), which will look at the upper atmosphere and provide us with information about carbon monoxide, oxygen and even hydrogen.

This is the UAE's first big planetary mission. Why go to the Red Planet?
We would like to develop the science and technology sector in the UAE – space missions accelerate the development of these two sectors rapidly. We'd also like to develop Emirati scientific capabilities and increase our contribution to the global science community in space and the field of planetary science.

What are the UAE's long-term goals at Mars?
In 2017, the UAE set out its vision in 'Mars 2117', a 100-year programme that looks into the settlement of the Red Planet. It shows an immense dedication into developing capabilities – when it comes to planetary exploration and looking at Mars long-term. It's a very realistic plan, which sets out a lot of steps on the way; the Hope mission is just the first of these. There are many projects in motion where we are developing our technology to help us realise our scientific visions, and there will also be a lot of outreach work to inspire students to go into science and technology. The name of the space probe, Hope, is an inspiration to everyone – inspiring youth and showing that a small country, like the United Arab Emirates, is attempting a huge space mission and is doing so successfully.


Telescope House
Telescope Specialists Since 1785
Web: www.telescopehouse.com
Email: sales@telescopehouse.com
Tel: 01342 837098
Sign Up
NEW - Bresser 6-inch Planetary Dobsonian. Comes with 2" Focuser, 25mm SuperPlossl 6x30mm FInder and Full Aperture White Light Solar Filter £299
NEW!
Explore Scientific iEXOS-100 Wifi Mount £349
Check out the Explore Scientific Deep Sky Cameras - all simple to use One Shot Colour systems featuring 1.7, 7.1 and 16 Megapixel Sensors. These cameras all feature set-point cooling and come with control software and heavy duty storage & carry cases.
16MP - £842
1.7MP - £1256
7.1MP - £2099
Bresser 25x70 Binoculars - £89
PMC EIGHT
PRECISION MOTION CONTROLLER
Explore Scientifc 127mm FCD100 Carbon Fibre Apo - £2287
Vixen BT126 Binoculars £3110
Vixen BT81S Binoculars £929
Vixen
At Telescope House
Introducing the Explore Scientifc 52-Degree Eyepiece Waterproof LER range from £59.99
Vixen SXD2-VC200L-S-PFL Telescope Package £3990
NEW!
Vixen FL55ss Fluorite Refractor. an ultra compact true fluorite element apochromatic refractor, ideal for widefield imaging & a "go anywhere" travel scope of the highest quality - £799
LUNT solar systems
Find the full range of ZWO Cameras at Telescope House From £151
Bresser Astrophoto Mount Package £439
NEW!
Introducing the new Lunt modular dual purpose Hydrogen Alpha AND conventional ED Refractors. Enjoy the convenience of two scopes in one, without sacrificing optical quality. ED Doublet 60mm from £2537. ED Triplet 130 version starting at £9230
ZWO ASIAIR Pro Wireless Scope control, Autoguiding & more.
Website: www.telescopehouse.com
Email: sales@telescopehouse.com | For sales and advice call: 01342 837098
All prices correct at time of press. Subject to change. Errors and omissions excepted.

THE SOUTHERN HEMISPHERE

With Glenn Dawes

Enjoy views of the bright star Regulus in the northern sky and deep-sky targets in Vela, the Sails

When to use this chart

1 Mar at 00:00 AEDT (13:00 UT)
15 Mar at 23:00 AEDT (12:00 UT)
31 Feb at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

MARCH HIGHLIGHTS

Mercury reaches greatest elongation west of the Sun on the 6th and is furthest from the Sun (by angular distance) in the morning – rising 30 minutes before dawn. March mornings are favourable for observing such events – or any planets in the dawn glow – from the Southern Hemisphere. This is when the ecliptic (the path of the Sun and planets) makes the steepest angle with the horizon, so Mercury achieves a maximum altitude for each degree from the Sun.

STARS AND CONSTELLATIONS

The bright star Regulus (Alpha (α) Leonis) is quite isolated in the northern evening sky. This Latin name means 'Little King', which is quite appropriate, as its the alpha luminary to the constellation of the king of the beasts, Leo, the Lion. Being the closest first magnitude star to the ecliptic it is often involved in rare planetary occultations; Venus occulted Regulus in 1959 and the same celestial bodies are involved in the next in 2044.

THE PLANETS

The early evening sky belongs to Uranus and Mars, with both setting at 22:00. Mars is low in the northwest at a similar brightness to nearby first magnitude star Aldebaran (Alpha (α) Tauri). The night sky is then devoid of planets until Saturn arrives (at 03:00 midmonth), with Jupiter less than an hour later. Mercury is favourable, low in the eastern sky at dawn's start. As Jupiter returns to the morning it passes this inner world, being closest on the 5th and separated by 0.5°.

DEEP-SKY OBJECTS

At the western end of the sails of the ship Argo in the constellation of Vela, the Sails, lies the famous multiple star, Gamma (γ) Velorum. There are many other doubles nearby also deserving recognition. One bright example is Dunlop 70 (RA 8h 29.5m, dec. -44° 44'). Lying 4° southeast from Gamma Velorum, it consists of blue and yellow stars (mag. +5.2 and mag. +6.9 respectively), separated by 4.8 arcseconds.

Close to the 'False Cross' asterism are a number of open star clusters. A great example is NGC 2910 (RA 9h 30.5m, dec. -52° 55'). Located 2.4° northeast from the bright star Kappa (κ) Velorum, this small cluster is composed of around 40 stars (mag. +10 to mag. +12) that are arranged in a crescent shape. Being surrounded by an impressive rich star field, the cluster can be hard to spot at first – enjoy finding it!

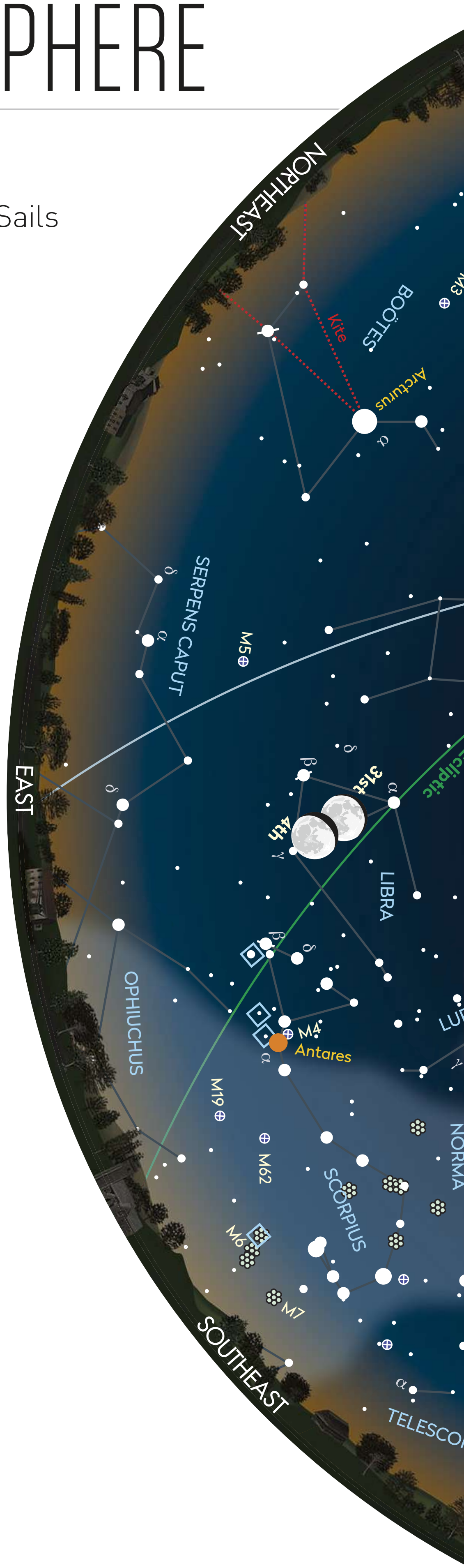
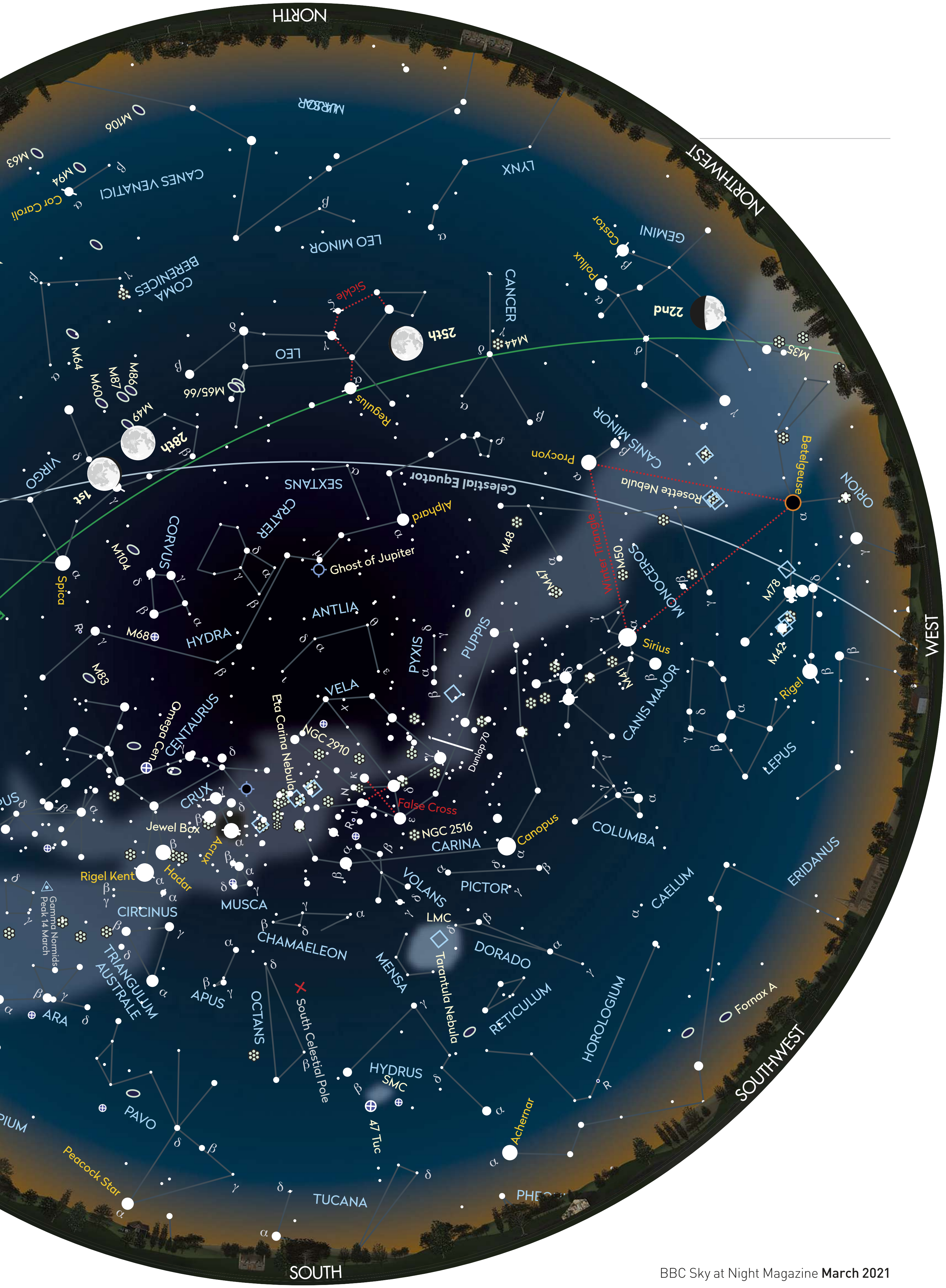
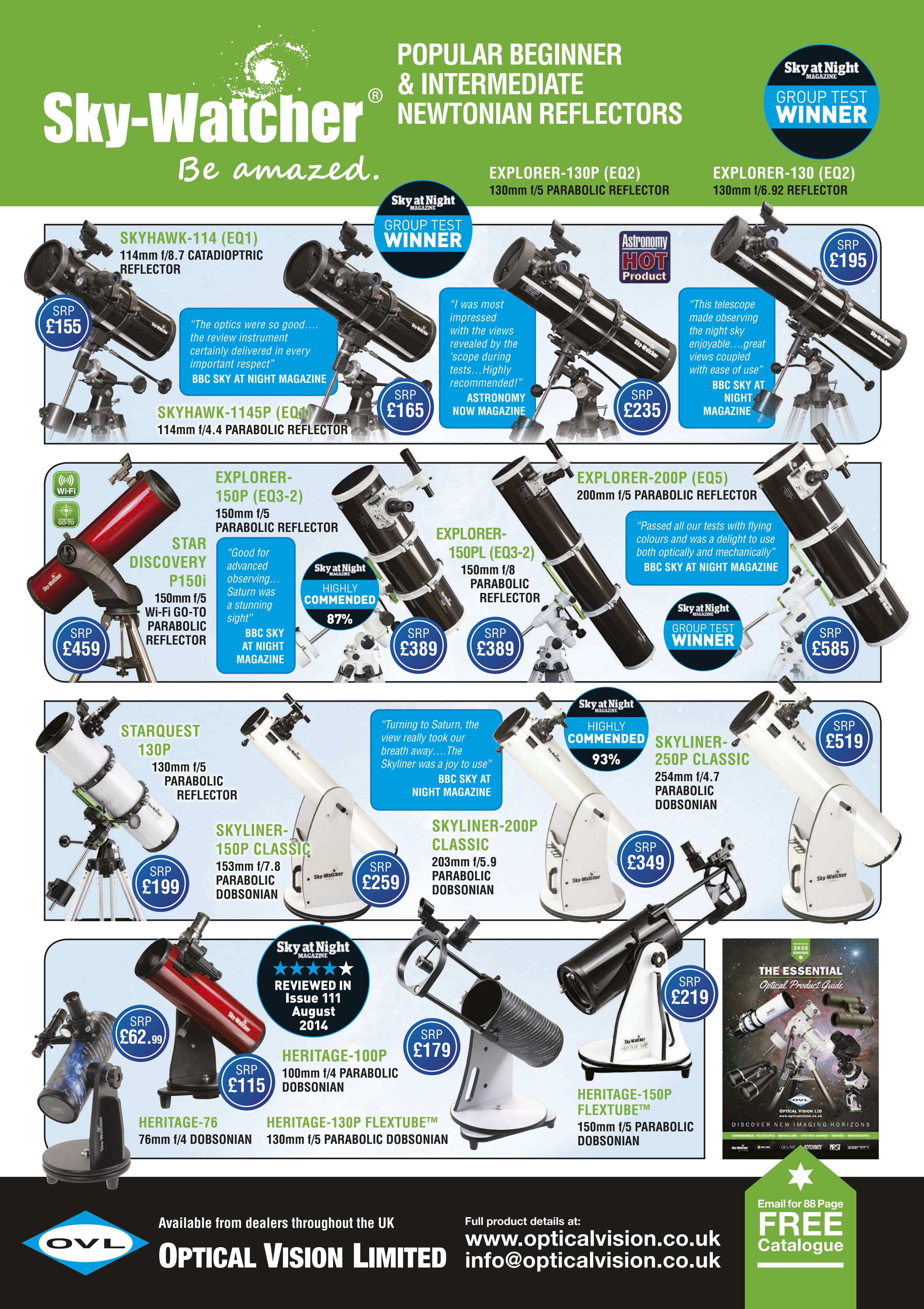


Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
LYNX
CANES VENATICI
Cor Caroli
M94
M63
M106
LEO MINOR
GEMINI
Castor
Pollux
22nd
COMA BERENICES
Sickle
CANCER
M44
M35
25th
LEO
Regulus
M64
M60
M87
M86
M65/66
M49
28th
1st
VIRGO
CANIS MINOR
Procyon
Betelgeuse
ORION
Celestial Equator
SEXTANS
Rosette Nebula
Alphard
CRATER
CORVUS
M104
M48
Spica
Ghost of Jupiter
M50
MONOCEROS
Winter Triangle
M47
M78
ANTLIA
HYDRA
M68
M83
PYXIS
PUPPIS
Sirius
M41
M42
CANIS MAJOR
Rigel
VELA
Eta Carina Nebula
NGC 2910
Omega Cen
CENTAURUS
Dunlop 70
LEPUS
CRUX
False Cross
Jewel Box
Acrux
NGC 2516
CARINA
Canopus
COLUMBA
ERIDANUS
Rigel Kent
Hadar
Gamma Normids Peak 14 March
CIRCINUS
MUSCA
VOLANS
PICTOR
CAELUM
LMC
CHAMAELEON
DORADO
TRIANGULUM AUSTRALE
MENSA
Tarantula Nebula
APUS
OCTANS
South Celestial Pole
RETICULUM
HOROLOGIUM
Fornax A
ARA
HYDRUS
SMC
47 Tuc
PAVO
Achernar
Peacock Star
TUCANA



Sky-Watcher®
Be amazed.
POPULAR BEGINNER & INTERMEDIATE NEWTONIAN REFLECTORS
Sky at Night MAGAZINE GROUP TEST WINNER
EXPLORER-130P (EQ2)
130mm f/5 PARABOLIC REFLECTOR
EXPLORER-130 (EQ2)
130mm f/6.92 REFLECTOR
SKYHAWK-114 (EQ1)
114mm f/8.7 CATADIOPTRIC REFLECTOR
SRP £155
Sky at Night MAGAZINE GROUP TEST WINNER
"The optics were so good…. the review instrument certainly delivered in every important respect"
BBC SKY AT NIGHT MAGAZINE
SKYHAWK-1145P (EQ1)
114mm f/4.4 PARABOLIC REFLECTOR
SRP £165
"I was most impressed with the views revealed by the 'scope during tests…Highly recommended!"
ASTRONOMY NOW MAGAZINE
Astronomy HOT Product
SRP £235
"This telescope made observing the night sky enjoyable….great views coupled with ease of use"
BBC SKY AT NIGHT MAGAZINE
SRP £195
Wi-Fi
GO-TO
STAR DISCOVERY P150i
150mm f/5 Wi-Fi GO-TO PARABOLIC REFLECTOR
SRP £459
EXPLORER-150P (EQ3-2)
150mm f/5 PARABOLIC REFLECTOR
"Good for advanced observing… Saturn was a stunning sight"
BBC SKY AT NIGHT MAGAZINE
Sky at Night MAGAZINE HIGHLY COMMENDED 87%
SRP £389
EXPLORER-150PL (EQ3-2)
150mm f/8 PARABOLIC REFLECTOR
SRP £389
EXPLORER-200P (EQ5)
200mm f/5 PARABOLIC REFLECTOR
"Passed all our tests with flying colours and was a delight to use both optically and mechanically"
BBC SKY AT NIGHT MAGAZINE
Sky at Night MAGAZINE GROUP TEST WINNER
SRP £585
STARQUEST 130P
130mm f/5 PARABOLIC REFLECTOR
SRP £199
SKYLINER-150P CLASSIC
153mm f/7.8 PARABOLIC DOBSONIAN
SRP £259
"Turning to Saturn, the view really took our breath away….The Skyliner was a joy to use"
BBC SKY AT NIGHT MAGAZINE
SKYLINER-200P CLASSIC
203mm f/5.9 PARABOLIC DOBSONIAN
Sky at Night MAGAZINE HIGHLY COMMENDED 93%
SRP £349
SKYLINER-250P CLASSIC
254mm f/4.7 PARABOLIC DOBSONIAN
SRP £519
SRP £62.99
SRP £115
Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 111 August 2014
HERITAGE-100P
100mm f/4 PARABOLIC DOBSONIAN
SRP £179
SRP £219
HERITAGE-76
76mm f/4 DOBSONIAN
HERITAGE-130P FLEXTUBE™
130mm f/5 PARABOLIC DOBSONIAN
HERITAGE-150P FLEXTUBE™
150mm f/5 PARABOLIC DOBSONIAN
2020 EDITION
THE ESSENTIAL Optical Product Guide
DISCOVER NEW IMAGING HORIZONS
OVL
Available from dealers throughout the UK
OPTICAL VISION LIMITED
Full product details at:
www.opticalvision.co.uk
info@opticalvision.co.uk
Email for 88 Page FREE Catalogue